scuolagalileiana di studi superiori

Università degli Studi di Padova

Galilean School course catalog

Class of Natural Sciences

Academic Year 2016-2017

Calculus

Teacher: Paolo Guiotto - UniPd - paolo.guiotto@unipd.it

Motivations.
The aim of the course is to introduce to mathematical modelling of biological systems through differential equations with particular emphasis both on modelling as well as on mathematical tools to discuss the qualitative behaviour of systems described in this way.

Targeted audience.
First year students.

Prerequisites.
No particular knowledge is required, the course is self-contained.

Syllabus.
1. Mathematical models – Malthus and logistic demographic models; multiple species models (prey-predator model and competition models); epidemic models (flu, smallpox, malaria).
2. Differential Calculus – infinitesimals, notions of derivative and main properties, elementary derivatives, rules of calculus, geometrical properties.
3. Calculus of primitives – notion of indefinite integral, elementary primitives, rules of calculus.
4. Differential equations – solution of the Malthus model, linear first order equations; solution of the logistic equation and discussion of the flu epidemic model; separable variables equations, the Cauchy problem and existence and uniqueness of solutions.
5. Systems of differential equations – existence and uniqueness, concepts of oriented orbit and phase portrait, first integrals, solution of the prey-predator model, equilibriums and their stability, linear systems, linearization theorem and local classification of equilibriums. Applications.

Teacher CV.
I'm researcher of mathematical analysis at University of Padova since 1998. I taught courses of mathematical analysis and probability for degree students of mathematics, physics and engineering and for PhD students in pure and applied math. My collaboration with the Scuola Galileiana goes back to 2005. Along these years I've been tutor and teacher of courses of mathematical analysis and probability. In particular I teach the course of Calculus since 2012.
My scientific interests are in the field of analysis on infinite dimensional spaces with particular attention to measures on infinite dimensional space and stochastic partial differential equations.

Textbooks/bibliography
Lecture notes.

Complements of analysis

Teacher: Davide Vittone - UniPD - vittone@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: Zermelo-Fraenkel axioms, cardinality, well-orderings, Zorn's lemma.
Inequalities (elementary and not): means, Holder, Minkowski, Jensen...
Convex functions: definition, derivatives, fine properties.
Elements of discrete dynamical systems: fixed points, attractive/repulsive fixed points, periodicity.
Time permitting, other miscellaneous topics will be treated.

Teacher CV.
Born in 1980.
1999-2003 Student at the University of Pisa with a fellowship from Scuola Normale Superiore.
2004-2006 PhD student at Scuola Normale Superiore. Advisor: prof. L. Ambrosio.
2007 Postdoc, University of Trento
2007-2014 Ricercatore (Assistant Professor) in Mathematical Analysis, University of Padova
2015-present Associate Professor in Mathematical Analysis, University of Padova
Research interests: Geometric Measure Theory and sub-Riemannian Geometry.

Textbooks/bibliography
T. J. Jech, *Set Theory*
G. H. Hardy, J. E. Littlewood, G. Pólya, *Inequalities*
R. L. Devaney, *A First Course in Chaotic Dynamical Systems: Theory and Experiment*

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 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 application and the comprehension of the formal structure.

Targeted audience.
The course targets the Natural Science Class of the Galileian School of the University of Padova, including students in Physics, Mathematics, Chemistry, Engineering, Biology, and Medicine. The ideal audience is supposed having 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.

- Macroscopic measurements
- Composition of thermodynamic systems
- Measurability of energy and heat
- Thermodynamic walls and constraints
- Thermodynamic equilibrium
- The fundamental problem of Thermodynamics
- Entropy and Energy representations
- The postulates of Thermodynamics
- Intensive parameters and equations of state
- Thermal, mechanical and chemical equilibrium
- The Euler equation
- The Gibbs-Duhem relation
- The simple ideal gas
- The ideal van der Waals fluid
- Electromagnetic radiation
- Possible, impossible, quasi-static, and reversible processes
- The maximum work theorem
- Engine, refrigerator, and heat pump performance
- The Carnot cycle
- Power output and endoreversible engines
- Legendre transformations
- Thermodynamic potentials
- The Gibbs potential and chemical reactions
- Response functions and Maxwell relations
- Stability of thermodynamic systems
- Le Chatelier's principle and Le Chatelier-Braun principle
- Role of symmetries in Thermodynamics

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 Galileian School of the University of Padova. He actively collaborates with Complex Systems groups at the Weizmann Institute in Israel, and Universidad Nacional Autonoma de Mexico (UNAM).

Textbooks/bibliography
H.B. Callen, *Thermodynamics and an introduction to Thermostatistics – Second Edition*, Wiley.
A number of problems and examples will be explicitly solved at the blackboard.

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 be then 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): Eherenfest 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
She published 8 articles on international journals and gave around 30 talks to students and experts of the field. Teaching: 2010&2011&2012: Probability and statistics – University of Bologna; 2012&2013&2014: Statistics – University of Padova; 2014: Introduction to Probability models- Galilean School of Padova. Since 2012, responsible of the FIRB project "Stochastic Processes and Interacting Particle Systems".

Textbooks/bibliography
1. F. Caravenna, P. Dai Pra. *Probabilità. Un primo corso attraverso modelli e applicazioni*, Springer (2013).
2. W. Feller. *An Introduction to Probability Theory and its Applications. I Volume*, Third edition, Wiley (1968).

For consultation:
3. P. G. Doyle, J.L. Snell*. Random walks and electric networks. Carus Mathematical Monographs, 22, Mathematical Association of America (1984). Available online.*
4. D. A. Levin, Y. Peres, E. L. Wilmer, *Markov Chains and Mixing Times*, American Mathematical Society, Providence, RI (2009). Available online. 5. O. Haggstrom. Finite Markov Chains and Algorithmic Applications. Cambridge University Press (2002). Available online.

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.
The exterior measure and the notion of measurable sets in Euclidean spaces. Measurable functions and definition of integrals for real or complex-valued functions. The monotone convergence theorem and the dominated convergence theorem. The space of integrable functions and the Riesz-Fischer theorem. The Fubini-Tonelli theorem. The Fourier inversion formula. The space of square integrable functions. An introduction to Hilbert spaces. Applications to Fourier series. The Fourier-Plancherel transform. Differentiation of the Lebesgue integral and the Hardy-Littlewood maximal function. Approximations to the identity and more general maximal functions.

Teacher CV.
Paolo Ciatti. Undergraduate Education: Laurea in Fisica, Università di Torino,1990. Thesis directed by Prof. Tullio Regge. Graduate Education: PhD in Mathematics, Politecnico di Torino,1995. Thesis directed by Prof. Fulvio Ricci. Academic Positions: Junior Researcher, University of New South Wales (Sydney),1996-1997. Ricercatore, Università di Padova, 1998-2008. Professore Associato, Università di Padova, 2008-present. Adjoint Professor, Dalhousie University (Halifax, Nova Scotia), 2013-present.

Textbooks/bibliography.
Folland, Gerald B. *Real analysis. Modern techniques and their applications*. Second edition. John Wiley & Sons, Inc., New York, 1999.
Royden, H. L. *Real analysis.* Third edition. Macmillan Publishing Company, New York, 1988.

Interaction Networks in Living Systems

Teacher: Amos Maritan - UniPD - amos.maritan@unipd.it

Motivations.
The understanding of living systems, which span 21 orders of magnitude in mass, needs more than a mere generalization of our knowledge of inanimate matter. However the use of the paradigm of interaction networks has allowed to tackle, in a unified framework, complex interdisciplinary problems in biology, ecology and social systems. Such problems exhibit recurrent and universal patterns reminiscent of certain thermodynamic systems poised near a critical point. The three main aims of the course are: 1) to stimulate a scientific attitude when facing a wide variety of natural phenomena without prejudice; 2) to be able to identify some of the key characteristics responsible for the emergence of a phenomenon; 3) to provide general tools, both analytical and numerical which are fundamental for the development of appropriate models for the phenomenon to be understood.

Targeted audience.
The program of the course has some flexibility and may depend, to some extent, on the preparation/ interests of students. This course can be held in the second or later year. It will be of interest for all students of the Galilean School. In the case all students attending the course are from natural science and engineering some sophisticated math will be utilized, otherwise the two courses of “Calculus” and “Probability” in the first year of the GS will be sufficient.

Syllabus.
Introduction: aims of the course; overview of various examples.
Network theory: deterministic and random networks; random walk on networks; electrical networks; Erdos-Renyi networks; degree distribution; Barabasi Albert model; Small Worlds. Scaling theory: Probability distribution function with and without a characteristic scale; playing with power laws; fat tailed distributions. Examples of power law distributions: body mass – metabolism scaling; power laws in cities; power laws in written human communication; spontaneous brain activity etc. Species interaction networks: Dynamical stability of large and complex interacting systems (with a brief introduction to the random matrix theory); complexity-stability paradox; mutualistic and antagonistic networks; emergence of nested interaction networks in mutualistic systems. Food trade networks: analysis of existing data and emerging patterns; dynamics of the food trade and its stability; Optimization principles in Nature: Examples of variational principles in physics; Natural selection and optimization; examples of optimization in interaction and transportation networks. Each “chapter” will have homework where each student is encouraged to find him/her-self examples and data where to apply the theory and the data analysis he/she has learnt.

Teacher CV.
Professional experience:
Prof. of Physics, Padova (2003 -)
Prof. of Physics, SISSA Trieste – Italy (1994 -2003), Associate Prof. of Physics, Padova (1991 - 1994), Associate Prof. of Physics , Bari (1987 - 2001), Associate Prof. of Physics, Padova (1983 - 1987)
Education and training: Physics degree at Padova (1979); Ph.D. in Physics at SISSA, Trieste (1983).
Accademic Appointments: Dean of the School of Excellence “Scuola Galileiana di Studi Superiori”, (2004 - 2010), Scientific consultant, ICTP Trieste – Italy (1997-2003), Correspondent resident member of "Istituto Veneto di Lettere Scienze ed Arti (2006-).
Thesis: About 30 PhD students, 40 undergraduate students.
Summary: The main field of interest is the equilibrium and non-equilibrium statistical mechanics. The main focus is on problems at the interface between physics and biology. > 300 publications in refereed journals including 4 in Science, 12 in Nature, 21 in Proc. Nat. Acad. (USA), and 64 in Phys. Rev. Lett.; 1 book co-edited; 1 patent. More at http://www.pd.infn.it/~maritan/index.html

Textbooks/bibliography
M.E.J. Newman, *Network: an introduction*, Oxford University press (2010). Only few chapters.
M.E.J. Newman, *Power laws, Pareto distributions and Zipf's law*, Contemporary Physics, Vol. 46, No. 5, September–October 2005, 323 – 351.
R. M. May, *Stability and complexity in model ecosystems*, Princeton University press (2001).
Chapters 1-3 and 7 and some parts of the remaining chapters.
Various articles will be proposed for each “chapter” of the course. The suggested articles will be chosen depending on the student interest and preparation.

Fluid Dynamics

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 biology and medicine 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 fluidynamics: 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. Geometrical and dynamical similarity.
Ideal flows. Two-dimensional flow of an inviscid fluid. Stream function and streamlines. The velocity potential and Laplace equation. Superposition principle. Circulation. Ideal flow past a cylinder. Magnus effect. Lift: why do planes fly ?
The stress tensor. Stresses in an incompressible fluid. The Navier-Stokes equations. Applications to one-dimensional flows: Poiseuille flow, fluid sheet on an inclined plane. Internal laminar flows. Flow in a conduct: critical Reynolds number and the entrance length, Poiseuille law. Flow between two plane-parallel plates: the Couette flow. Lubrication. The boundary layer for a plane surface, Blasius solution. The boundary layer for a curved surface. Viscous flow past a sphere (Stokes flow) and a cylinder. Geostrophic flows and the Ekman boudary layer.

Teacher CV.
Roberto Turolla got 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 a senior associate 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 170 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)

Data Analysis and Statistics

Teacher: Giulio D'Agostini, University of Rome “La Sapienza” - giulio.dagostini@roma1.infn.it
https://www.roma1.infn.it/~dagos/

Motivations.
The course will focus on probabilistic reasoning and its applications in data analysis in order to infer model parameters (e.g. 'fits'), to compare models and to make probabilistic predictions.
Extensive use of graphical models will be made, i.e. of models which describe the network of causes and effects.
Practical aspects of probabilistic computation will be covered, including methods based Markov Chain Monte Carlo. Many example will be made, using the R language as the 'lingua franca' of the course, although the use of some free (or demo version of) packages for special purposes will be illustrated (like e.g. WingBUGS, Jags and AgenaRisk).

Targeted audience.
Second year students, which are assumed to have followed "Introduction to probabilistic models" during the first year.

Syllabus.
Uncertainty and probability in the Sciences. ISO Guide on Uncertainty (GUM). Basic rules of probability for discrete and continuous variables.
Summaries of distributions and general theorems. Bernoulli process and related distributions: Geometric, Pascal and Binomial. Poisson process and related distributions: Poisson,
Exponential, Erlang. Gaussian ('normal') distribution, its importance and related distributions. Multivariate distributions, in particular normal multivariate, including conditioning in many dimensions. Direct sampling with Montecarlo (MC) methods. Propagation of uncertainties: from exact to approximate methods. Probabilistic inference. Parametric inference applied to basic models. Beta and Gamma distributions and their use in inference.
Treatment of uncertainties due to systematics. Bayesian Networks as conceptual and practical tools. Computational issues in probabilistic inference overcome by MC sampling: importance sampling; Metropolis(-Hasting) algorithm; Gibbs sampler; simulated annealing; nexted sampler.
Recovery of 'standard formulae' as special cases of the general probabilistic approach under well stated conditions.

Teacher CV.
Giulio D’Agostini is associate professor at the University of Rome La Sapienza.
He has collaborated in large experiments at CERN (Geneva), DESY (Hamburg) and LNF (Frascati), and he is presently member of NA62 and of KLOE.
His expertise range on various aspects of the construction and the operation of detectors, and on the analysis of the resulting data. Physics topics to which he has contributed include: study of the force between quarks and gluons; quark fragmentation; heavy quark decays; proton and photon structure function; search of new particles and phenomena, such as dibaryons, excited quarks, supersymmetric particles, electron compositeness and Higgs boson.
He is also interested in the fundamental aspects of probability theory, as well in its teaching and its applications in data analysis and in decision making processes.

Textbooks/bibliography
Mainly freely available resources, including teacher's notes and preprints
(see e.g. https://www.roma1.infn.it/~dagos/prob+stat.html).

Thermodynamics Of Non-Equilibrium States

Teacher: Giorgio Moro - UniPD - giorgio.moro@unipd.it

Motivations.
In many fields of science, engineering and medicine, the study of complex material systems and their time evolution is required on the basis of macroscopically measurable properties. The classical thermodynamics and its extension to irreversible phenomena provide the essential tools for treating these this kind of problems within an unified framework. The course will focus on the thermodynamical description of non-equilibrium processes with reference also to their interpretation at the molecular level.

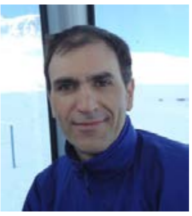
Targeted audience.
Third year students of science, engineering and medical curricula, with an established background on the principles of equilibrium thermodynamics and their applications to material systems.

Syllabus.
Methods of non-equilibrium thermodynamics: chemical kinetics and heat diffusion as simple case studies.
How to solve diffusion equation?
Irreversible processes in simple fluids: viscosity.
Mass transport by diffusion.
Brownian motion: a molecular picture of diffusion processes.
Chemical kinetics controlled by diffusion.

Teacher CV.
Giorgio Moro has got the University degree in Chemistry in 1975 and, after two years of post-doc at Cornell University (Ithaca, N.Y., USA), has been research assistant and associate professor at Padua University and Parma University. Presently he is full professor of Physical Chemistry at the Department of Chemical Sciences of Padua University.
His main research interests concern Theoretical Chemistry with applications to the study of molecular dynamics in condensed phases, like: interpretation of dynamical effects in Magnetic Resonance, conformational dynamics, molecular models of activated processes, structure and transport properties of liquid crystals, statistical properties of quantum pure states.

Textbooks/bibliography
I. Prigogine, *“Introduzione alla Termodinamica dei Processi Irreversibili”* (Leonardo, 1971, Roma)
S.R. de Groot, P. Mazur, *“Non-equilibrium Thermodynamics”* (Dover, 1984, New York).

Biology, genetics and biotechnology of plants



Teacher: Livio Trainotti - UniPd – livio.trainotti@unipd.it

Motivations.
Plants are primary producers at the base of any ecological system. We also depend on plants for our everyday life. Starting from simple observations and considerations we will discover the peculiarities that make plant attractive as models to investigate basic biological questions and how the answers we can get can help us in developing the knowledge we need to cope with climate changes and the growth of the human population that we are facing now and in the coming years.

Targeted audience.
Students of the Natural Science Class of the Galilean School. Students of other classes are welcome.

Prerequisites.
No particular knowledge is required; the course is self-contained.

Syllabus.

1. Biology of plants (8 hours)
    a. Cellular organization of plant organisms (particular emphasis will be on the cellular compartments of the typical eukaryotic plant cell, that are the cell wall, plastids and vacuoles).
    b. Tissues and organs of plants (this part will be focused on the cell types that constitute the major plant tissues, and how these are organized to give rise to organs of the body of the plant, both in the so called primary structure, that originates from the apical meristems, and in secondary structure, which originates from the lateral meristems).

2. Genetics of plants (8 hours)
    a. The biological cycle of the plants.
    b. Organization of the genetic material in plants.
    c. Evolution of plant genomes.
    d. Increase in ploidy level.
    e. Genetic improvement in self-pollinating species.
    f. Genetic improvement in cross-pollinating species.

3. Biotechnology with plants (14 hours)
    a. Vegetative reproduction in plants.
    b. In vitro plant propagation.
    c. Techniques for the production of genetically modified plants (GMP, or transgenic; first generation, GMO).
    d. New technologies for plant breeding: cisgenesis and genome editing.
    e. Outline the use of GMPs in agriculture.
    f. Outline the regulatory aspects that regulate the production and consumption of GMPs.

Teacher CV.
Livio Trainotti, born in 1968, is associate professor of Botany at the Department of Biology, University of Padova, since 2006. He holds a MS in Biology (1992) and a PhD in Evolutionary Biology (1997). His main research interest is the investigation of the genetic and physiological mechanisms regulating fleshy fruit development and ripening with the final hope to produce fruit of better quality, with a better taste, with improved nutritional properties, lasting longer after harvest and needing less energy, water and economic resources to be produced and to reach consumers' table. According to the Scopus database, L. Trainotti co-authored 51 publications, most of them describing findings in his favorite plants that are strawberry, tomato, apple and peach.

Textbooks/bibliography
Lecture notes.

Foundations of differential geometry

Teachers: Carla Novelli and Franco Cardin UniPD– novelli@.unipd.it, franco.cardin@unipd.it,

Module 2. Syllabus.
--Cohomology in R^3: grad, curl and div are representations of the exterior differential
--Pull-back and push-forward for tensor
--Lie derivative, with respect to vector fields, of tensors
--Commutation of flows and vanishing Lie-brackets
--Symplectic manifolds
--Isotropic, co-isotropic and Lagrangian submanifolds
--Examples of Lagrangian submanifolds
--Hamiltonian systems
--Geometrical theory of Hamilton-Jacobi equation
--Hamiltonian Variational Principle
--Theory of the Invariant Integral of Poincaré-Cartan
--Conjugate points as obstruction to the uniform convergence minimum of critical curves for Tonelli Lagrangian functions
--Weak theory of Calculus of Variations in H^1
--Morse index theory and Morse theorem

Teacher CV
Franco Cardin. Laurea in Physics, Univ. of Padova. He has been CNR researcher, universitary researcher, associate professor, since 2000 he is full professor in mathematical physics, MAT07, at the Department of Mathematics of the University of Padova. Scientific interests: continuum thermo-mechanics and phase transitions; the global theory of Hamilton-Jacobi and allied variational theories of symplectic topology; topics on exact finite reduction in field theory. Recent international research collaborations: in symplectic topology, with the Ecole Polythecnique; in molecular dynamics, with the Computational Laboratory of Zurich. F.C. spent periods of study and research at the Foettinger Institut of the TU of Berlin, guest of Prof. Ingo Mueller; at the university Paris VI, guest of Prof. Charles Marle, at the Ecole Polythecnique, guest of Prof. Claude Viterbo, director of the Centre de Mathematiques Laurent Schwartz. He is member of the Scientific College and Coordinator of Course of Studies in "Mathematics" of the "Scuola di Dottorato in Matematica" of Padova.

Module 2. Textbooks/bibliography
F. Cardin, *Symplectic Topology and Mechanics. Lecture Notes of the Unione Matematica Italiana*, 16. Springer, Cham, 2015. xviii+222 pp.
B. A. Dubrovin, A. T. Fomenko, S. P. Novikov, *Modern geometry---methods and applications*. Part III. *Introduction to homology theory. Graduate Texts in Mathematics*, 124. Springer-Verlag, New York, 1990. x+416 pp.
J. Milnor, *Morse theory*. No. 51 Princeton University Press, Princeton, N.J. 1963 vi+153 pp.

Introduction to Cognitive Neuroscience

Teachers: Mathew E. Diamond – diamond@sissa.it , Davide F. Zoccolan – zoccolan@sissa.it, Domenica Bueti – domenica.bueti@sissa.it, Davide Crepaldi – davide.crepaldi@sissa.it

Motivations.
This course will introduce students to many of the fundamental concepts and methods of cognitive neuroscience. The students will learn that the fundamental issue in cognitive neuroscience is to uncover the causal relationships between brain activity and behavior. Approaches to this issue, both in human and animal subjects, will be explored. Behavior includes perception, decision making, and language.

Targeted audience.
The course is designed for curious and enthusiastic students who wish to explore the biological basis of our experience of the world. Although it is not necessary to have previous training in math, statistics, or physics, an aptitude and interest in quantitative approaches is helpful.

Syllabus.
Introduction to Cognitive Neuroscience in 4 modules; guest lecturers from SISSA

Module 1 - Tactile Perception
Instructor: Mathew E. Diamond, http://www.sissa.it/cns/tactile
The module will focus on the basic principles of organization of the sensory pathways and their target regions of cerebral cortex; mechanisms and properties of sensory transduction; psychophysical methods for quantifying sensory perception; methods for quantifying the relationship between neuronal activity and behavioral performance, with a focus on several lines of inquiry spanning tactile, auditory, and visual perception.

Module 2 - Visual perception
Instructor: Davide Zoccolan, http://people.sissa.it/~zoccolan/VisionLab/Home.html
The module will focus on the structure and functions of the mammalian visual systems, with a special emphasis on shape processing and object recognition. In addition, the module will include a description of some of the computational approaches that allow modeling and understanding visual functions. In particular, the module will introduce the students to: 1) quantitative models of neuronal tuning (e.g., reverse correlation approaches); 2) feedforward neuronal networks for object recognition; and 3) functional models of the visual system using basic machine learning approaches.

Module 3 - Human brain imaging
Instructor: Domenica Bueti,
Currently moving to SISSA, previous website:
https://www.unil.ch/line/en/home/menuinst/people/domenica-bueti.html
The module focuses on the analysis and characterization of neuroimaging and brain stimulation data, including functional Magnetic Resonance Imaging (fMRI) and Transcranial Magnetic Stimulation (TMS). The lectures will cover brain stimulation and imaging technology, current techniques for experimental design and analysis, and a discussion of the merits and limitations of these techniques as tools for cognitive neuroscientists.

Module 4 - Language, reading and the brain,
Instructor: Davide Crepaldi, http://www.davidecrepaldi.net
The module offers an introduction to how the brain deals with language and reading. It does so by focusing on the relationship between form and meaning, notably described by linguistic morphology. The approach is primarily experimental, although we will strive to connect brain data with theoretical linguistics. We will cover both classic approaches based on factorial experiments and box–and–arrow models; and more quantitative approaches based on information theory and other types of mathematical formulation.

Teacher CV.
To be furnished later.
Please see webpages in the links above.

Textbooks/bibliography
Each lecturer will provide his/her own sources.

Probability and introduction to stochastic processes

Teachers: Paolo Dai Pra - UniPd – daipra@math.unipd.it

Motivations.
The purpose of the course is to present some fundamental stochastic models with temporal structure. In particular the fundamental results in stochastic analysis will be given, with emphasis on applications.

Targeted audience.
Students enrolled in a degree in natural or social sciences. Basic knowledge of calculus and elementary probability will be assumed.

Syllabus.
The program could in principle be calibrated to the audience. A possible program is the following.
1. Martingales and urn models.
2. Brownian motions and diffusions. Applications
3. Jump processes.

Teacher CV.
Paolo Dai Pra is Full Professor in Probability and Mathematical Statistics at the Department of Mathematics of the University of Padova. Besides the teaching activity at the undergraduate level, he has delivered several courses for the Doctoral School in Mathematical Sciences and the Galilean School. His research interests are mainly concerned with stochastic models for systems of many interacting components, their thermodynamic limit, phase transitions, fluctuations, large deviations and convergence to equilibrium. More details are available at: www.math.unipd.it/~daipra.

Textbooks/bibliography
G.F. Lawler, Stochastic Calculus: An Introduction with Applications, 2014, Lecture Notes.

Quantum information I e II


Teachers: Paolo Villoresi and 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 information, from the theoretical and the experimental point of view. Quantum information is the merging of two big scientific revolutions of the XX century, namely Quantum Mechanics and Information Theory. Thank to the counterintuitive features of quantum mechanics (i.e. entanglement, uncertainty principle, no-cloning theorem) it is possible to manipulate and to transmit information in an unconventional way, with increased capabilities with respect to classical physics protocols. First, we will introduce the basic tools in quantum information formalism. During the course, it will be introduced how by manipulating quantum bits (or qubits) it is possible to achieve speed-up in computation, security in communication and generation of secure random numbers. Some laboratory experience (within the 30 hours of the course) will be set up to demonstrate the physical principles introduced in the course.

Targeted audience.
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.
Quantization of electromagnetic field, coherent states, statistic of light detection, quantum information, entanglement, tomography of quantum state, generation of entangled photons, Bell's inequalities, quantum key distribution, quantum communication, quantum computation, quantum algorithms, quantum random number generators.

Teacher CV.
Paolo Villoresi is Full Professor in Physics at the Department of Information Engineering of the University of Padova. He is author of more than one hundred articles in international journals. He teaches Electromagnetism for the Bachelor degree in Electronic Engineering and “Laser and Quantum Optics” for the Master degree in Electronic Engineering. He is the Group Leader of the QuantumFuture research group, which is active in the Quantum Information and Communications. He was a member of the Board of the Institute of Photonics and Nanotechnology of the National Research Council from the foundation to 2015. He has served as coordinator of several national and international research projects, including, in addition to space quantum communication, the generation of ultrafast coherent radiation and the application of lasers in Medicine and Industry. He is the co-inventor of 11 industrial patents and patent applications.

Giuseppe Vallone is Assistant Professor in Physics at the Department of Information Engineering of the University of Padova. He is author of more than 60 original research articles in international journals. He teaches Electromagnetism for the Bachelor degree in Informatic Engineering. His research is focused on quantum information, generation and applications photon states, quantum nonlocality tests, quantum computation, quantum communication and quantum random number generators.

http://quantumfuture.dei.unipd.it/

Textbooks/bibliography
1) G. Benenti, G. Casati, G. Strini, *“Principles of Quantum Computation and Information - Volume I: Basic Concepts* and *Volume II: Basic Tools and Special Topics”* (World Scientific, 2004).
2) M. A. Nielsen and I. L. Chuang *“Quantum Computation and Quantum Information”* (Cambridge 2010).

Methods of experimental physics for life sciences

Teachers: Giovanni Carugno– UniPd – carugno@pd.infn.it, Riccardo Faccini- University of Rome "La Sapienza"- riccardo.faccini@roma1.infn.it.

Motivations.
Translational research from physics to life sciences requires communication between physicists, biologists and physicians. A formation across these disciplines to set a common ground is therefore crucial. The course will introduce to the basic concepts related to physical phenomena used to probe biological matter. Elementary knowledge of the various underlying physics mechanisms connected to the medical and biological instruments will be presented.

Targeted audience.
III year students of all disciplines. Only basic physics background is required.

Syllabus.
1) Nuclear Magnetic Resonance Spectroscopy: from Theory to Imaging
2) Electron Paramagnetic Resonance as Molecular probe
3) Infrared and Ultraviolet Spectroscopy : Absorption and Fluorescence
4) X Rays : from Generation to TAC imaging
5) Radiation & Matter Interactions
6) Radio Therapy Principles: Standard, Metabolic and Hadrontherapy
7) Nuclear Decay Chains : Opportunities in Medical Physics

Teacher CV.

Giovanni Carugno: Laurea Degree (May 1986) Physics, University of Roma "La Sapienza" (laurea Summa cum laude). Supervisor: Prof. M. Conversi. Student Associate at Cern and Brookhaven National Laboratory (1985 - 1986). CERN fellow (1987 – 1988) ; Supervisors: Prof. C. Rubbia, M. Ferro-Luzzi. Associate Scientist at Legnaro National Laboratory (1989 – 1992). Researcher at INFN Sezione di Padova (1993 – 2002). Visiting Scientist at Paul Scherrer Institute (PSI – Zurich) (1993 – 1994). Visiting Scientist at CERN and ESPC Paris under European Contract provided by Prof. G. Charpak (1996). 1° Ricercatore at INFN Padova (2002 – 2013). Research Grant from Schwinger Foundation (2008). Distinguished Member of European Casimir Network ESF (2008 – 2013).

Riccardo Faccini: graduated in 1994 and till 2008 worked in particle physics experiments, searching the Higgs boson at CERN first and studying the matter-antimatter asymmetry at Stanford next. In last years he has concentrated on applied physics activities, working on the improvement of the dose evaluation in particle therapy and in the development of a novel radiation-guided therapy for complete tumor excision. Assistant professor at the University of Rome "La Sapienza", since 2014 he teaches, among other courses, Medical Physics. He is also involved in several outreach projects, including the Italian podcast of "every-day physics", FISICAST (www.radioscienza.it/fisicast).

Textbooks/bibliography
Notes from the course of Prof. P. Corvisiero,
https://www.ge.infn.it/~corvi/doc/didattica/radioattivita/lezioni/
Notes from the lessons

Introduction to Nonlinear Partial Differential Equations

Teacher: Nicola Garofalo – UniPd –nicola.garofalo@unipd.it

Motivations.
Partial differential equations (PDEs) are expressions involving an unknown function of two or more variables and a certain number of its partial derivatives. Such equations govern the phenomena of the physical world, and they play a preeminent role both in pure mathematics and in the applied sciences:

- The small vibrations of the string of a violin are described by the *wave equation*, a PDE that is ubiquitous in the description of undulatory phenomena.
- The potential of the gravitational field generated by a certain distribution of mass satisfies (away from the mass itself) a PDE that is known as *Laplace equation.*
- The distribution of temperature in a conducting body is described (at least near the source) by yet another PDE known as the *heat equation*. These are instances of PDEs of linear type.

But many phenomena of interest in our everyday life are not described by linear equations. Nonlinear PDEs whose study has led to beautiful and fundamental advances in mathematics during the 20th century; are: the minimal surface equation; the Monge-Ampère equation. The principal aim of this course is to bring the audience to mastering some of the basic aspects of PDEs, beginning with the linear models described above. The second part of the course will be devoted to providing the audience with a glimpse into some of the fascinating aspects of nonlinear PDEs.

Targeted audience.
This course will be completely self-contained, and can be profitably followed by any student who has had a good exposure to the fundamentals of calculus of one and several variables. In fact, some of these fundamentals will be recalled in detail during the lectures.

Syllabus.
Fourier transform in Rn. Solution of the Cauchy problem for the wave equation in the physical space-time. Huyghens principle. Cauchy problem for the heat equation. Properties of the heat semigroup. Laplace equation, sub- and super-harmonic functions. Koebe's theorem. Hypoellipticity of Laplace equation: the theorem of Caccioppoli-Cimmino-Weyl. Strong maximum principle. Overdetermination and symmetry. The soap-bubble theorem of A.D. Alexandrov.

Teacher CV.
Education: Ph. D. in Mathematics, University of Minnesota; Laurea in Mathematics, University of Bologna.
Research Interests: Partial Differential Equations; Harmonic Analysis; Riemannian and subRiemannian Geometry.
Academic Appointments: 1990-, Professor of Mathematics, Università di Padova; 1987-89, Associate Professor of Mathematics, Università di Bologna; 1980-86, Assistant Professor of Mathematics, Università di Bologna.
Other Positions: Visiting Professor, Imperial College, London; Visiting Professor, Inst. H. Poincaré, Paris; Visiting Fellow, I. Newton Inst. for Mathematical Sciences, Cambridge; Distinguished Visiting Professor of Mathematics, The Ohio State University, Columbus, Ohio; Professor of Mathematics, Purdue University, W. Lafayette, Indiana; Visiting Professor of Mathematics, The J. Hopkins University, Baltimore, Maryland; Visiting Professor, The Mittag-Leffler Institute, Djursholm, Sweden; Visiting Professor of Mathematics, University of Maryland, College Park, Maryland; Visiting Professor, The Institute for Advanced Study, Princeton, New Jersey; Associate Professor of Mathematics, Purdue University, W. Lafayette, Indiana; Assistant Professor of Mathematics, Northwestern University, Evanston, Illinois.
Teaching Award: Recipient of the 2012 USA Ruth and Joel Spira Award for excellence in graduate teaching.
Amer. Math. Society, Citation Index: Author of 114 publications in international journals.
Cited 2259 times by 949 authors in MathSciNet.
Editorial Boards: 1. Nonlinear Analysis Series A: Theory, Methods & Applications. 2.
Analysis and Geometry in Metric Spaces. 3. Journal of Dynamical and Control Systems.

Textbooks/bibliography
Lecture notes of the course will be made available to the students.