Educational program 2022/23

PhD Program in Mathematics, Physics and Applications to Engineering

XXXVIII cycle

Courses

University Training activities

Research and intellectual property enhancement activities

Patent as an inventive research activity (4 ECTS – 24 hours)

The course focuses on patenting principles, practices and strategies in the processes of intellectual property management and enhancement and technology transfer at national and international level.
The lessons aim to promote the exploitation of research results through the protection of Intellectual Property (IP), providing tools and methods on procedural forms and steps to structure patent applications.
Specifically, they will concern the principles of Intellectual Property protection, patent submission and evaluation procedures, information on how to retrieve data on existing patents (anteriority search) and the necessary bibliographical tools.

Syllabus

1. *Patent Making* - Theories – Laboratory

- The Patent between Invention and Innovation
- Forms and types of patents
- Definition and practice of the patent for industrial invention
- Patentability requirements
- Good practices for structuring a patent application for an industrial invention
- Procedure for depositing and/or extending the patent
- Patent searches and classification codes
- Definition and practice of the utility model
- Comparison between patent for industrial invention and utility model patent
- Registration of designs and models
- Rights on inventions
- Practical laboratory on Intellectual Property: use of databases and setting up patent proposals

2. *Processes, tools and best practices to structure patents and models* - Theories – Laboratory

- Impact of Intellectual Property on Research
- Overview of industrial invention patents examples
- Overview of designs and models examples
- Practical laboratory on intellectual property: simulation of patent research proposals
- Presentation and explanation of patent proposals
- Round table to discuss the proposed patent files

3. *Strategies and forms of patent valorisation* - Theories – Laboratory

- Tools and opportunities for Intellectual Property valorisation
- Presentation of Innovation Awards and Competitions: Start Cup Campania, National Award for Innovation
- Overview of examples and mock-ups of Business model and Business plan
- Spin off as a tool for research valorisation
- Overview of academic spin-off examples
- Facilitated finance instruments
- Practical laboratory on Intellectual Property: patent valorisation and technology transfer
- Structuring business models to simulate start cup and spin off creation

Language, computer training activities and data management

English Language (4/6 ECTS – 24-32 hours)

Introduction to modern computing infrastructures (4 ECTS – 20 hours)

Lecturer: M. Iacono (UniCampania)

The course aims at providing students of Dottorato di Ricerca in Matematica, Fisica e applicazioni per l'Ingegneria the basic knowledge related to modern computing infrastructures, presenting the main issues on a small and large scale, to allow an appropriate and wise use for the needs of usage and development of specialized computing applications for research problems. After an introduction about the characteristics of modern computing nodes and computer networks, the course presents the main themes related to architecture, organization and software support offered by contemporary large scale computing systems, with special reference to massively distributed architectures and cloud applications. Finally, the course includes a primer on the issues related to performance evaluation for these systems and related modeling techniques. The course includes references to related research activities about research topics.

Data Management (4 ECTS – 16 hours)

Data are now recognized as a major organizational resource to be attained and managed like other assets such as land, labour and capital. The ability to structure, access, manage and leverage this valuable resource is becoming more and more critical to all organizations, large or small, public or private.

This course is designed to present the fundamental concepts and theories in data management, in order to promote their application to research activities and professional practice. An examination of Database Management Systems, database architectures, the role of data in decisional processes and the processes that guide the data lifecycle will be a focus of the course. Due to the importance of personal data in scientific research, it is mandatory to include in the course the main concepts about personal data protection regulation.

Contents:

1. Data Management basics: Information need, sources and users; data attributes; relationship among data; the data life cycle.
2. The conceptual database models utilizing entity-relationship model: design of data structures that will limit redundancy and enforce data integrity.
3. The logical database model as the second step of database design: the relational data model in terms of data structure, data integrity, and data manipulation. Notes on data definition, manipulation and query languages (SQL).
4. The role of data in Decision Support Systems: multidimensional data model; operational and informational systems; Data warehousing systems and OLAP analysis; Data Mining.
5. Introduction to Big Data and large database and unstructured databases for scientific applications.
6. Data management and personal data protection regulation: ethics of privacy; basics on GDPR regulation: general principles, right of users, accountability and policies; GDPR rules on personal data in the scientific research.

Specialistic courses

Spline models for regression analysis

Lecturer: R. Campagna (UniCampania) (4 ECTS - 20 hours)

Smoothing and interpolating spline models have attracted a great deal of attention in recent years and have been widely used in many areas of science and engineering, such as signal and image processing, computer graphics, and recently, geometric deep learning and neural networks. Particularly, Smoothing spline functions are a powerful tool in the functional analysis and regression framework, to model and predict data trends.

The course aims at introducing basic smoothing spline models, including polynomials and L-splines, and penalized splines, as well as an overview of more advanced models, including nonparametric nonlinear regression splines. Two models are described in detail: smoothing splines and regression splines. Penalized least squares regression models, and methods for model selection and inference are also discussed.

Some applications of smoothing splines to real data are presented.

An interactive hands-on session where students will apply smoothing splines to simple problems using Matlab is also included.

Syllabus

1. Motivating applications: Signal and image processing, Computer graphics, Geometric deep learning and neural networks
2. Spline functions: Parametric and nonparametric regression, Polynomial splines, Interpolating splines
3. Spline bases: Truncated power basis, B-splines
4. Smoothing and regression models: Smoothing splines, Regression splines, Penalized regression splines

Principle of non-Newtonian Fluid Mechanics (4 ECTS - 20 hours)

Lecturers: C. Carotenuto (UniCampania) - M. Minale (UniCampania)

The aim of the course is to teach the first concepts of the mechanics of non-Newtonian fluids and their characterization so to be able to choose the best constitutive equation for each material, homogeneous or heterogeneous. These skills are necessary for the analysis and design of conventional and innovative materials and related production processes.

Short introduction to rheology and its various field of application.

Constitutive equations. Newtonian and non-Newtonian fluids. Classification of non-Newtonian behaviours: dilatant, pseudo-plastic and plastic.

Modelling: Principles of continuous mechanics. Pure viscous fluids: Reiner-Rivlin fluid, Generalized Newtonian fluid; Viscoelastic Fluids: Maxwell Fluid, Simple Fluid, Coleman and Noll Second Order Fluid, Fading Memory.

Rheometry: Classification of rheometers. Rotational and capillary rheometers. Equation of rheometers: Simple Shear, Small-gap Couette, Cone-Plate, Plate-Plate, Large-gap Couette, Capillary Viscometer.

Experimental techniques, time-temperature superposition. Dynamic-Mechanical Spectroscopy: Analysis of viscoelastic properties of materials with oscillatory experiments.

Heterogeneous materials: Overview of the constitutive properties of emulsions (cosmetic creams, mayonnaise, polymer blends, etc.), suspensions (slurries, peanuts butter, etc.), gel (gelatin) and foams (expanded polystyrene, shaving foam, cream, etc.).

Pyro-electrohrdrodynamics and advanced technologies for soft-matter manipulation (4 ECTS - 20 hours)
Lecturers: S. Coppola (ISASI) - S. Grilli (ISASI)

The course provides the description and exploitation of innovative fabrication methods for the manipulation of liquids, polymers, and high viscous materials. In particular, the method based on the pyro-electrohrdrodynamic (pyro-EHD) effect will be presented focusing on different materials, high resolution printing and patterning properties. The main feature of the method discussed stands in the non-contact and nozzle free modality that allows to manipulate starting drops of the material of interest in a direct way. The course will be focused on the theory of the pyroelectric effect and its experimental exploitation for the manipulation of soft matter, opening towards its feasible application in different field of technologies. A cross-overview with the advanced conventional technologies will be provided while the main properties and advantages of the pyro-EHD will be discussed for biomedical application, additive manufacturing of 3D microstructures and for functionalization of microfluidic lab-on-chip devices.

Theory of nuclear forces (4 ECTS - 20 hours)

Lecturer: L. Coraggio (UniCampania)

The goal of this course is to introduce PhD students to our present knowledge of the theory of nuclear forces. First, the basic phenomenological features of the nuclear potential are presented, and their connection to the main aspects of strong force. Then, we start to follow the path that from the Yukawa potential, through models based on the meson theory, historically leads to the present approach to the derivation of two- and three-body nuclear forces which are rooted in the QCD by way of the effective field theory. Last section is devoted to study the nuclear environment that is considered the best testing ground for models of nuclear forces, that is the infinite nuclear matter. To this end, basic knowledge of the derivation of the equation of state of nuclear matter in terms of the Brueckner theory will be provided to the students.

An Introduction to Lynear Dynamics (4 ECTS-20 hours)

Lecturer: E. D'Aniello (UniCampania)

The course begins providing the students with fundamental concepts of (not necessarily linear) dynamical systems. It focuses on the Birkhoff transitivity theorem and a close study of various properties related to chaos. Then all the given notions and results are revisited in the linear context.

Introduction to Set Theory Dynamics (4 ECTS-20 hours)

Lecturer: P. D'Aquino (UniCampania)

We will introduce the axioms of Zermelo Fraenkel (ZF), and develop the theory of ordinals, cardinals and their arithmetic. The transfinte induction will be also presented. Constructions of models of ZF. Axiom of choice and its equivalents. Independence results in set theory, in particular we will show the independence of the axiom of choice and of the continuum from the axioms of ZF. The constructible universe due to Godel in 1936, and the forcing method introduced by Cohen in 1963 will be analyzed. Some consequences of the independence of the continuum hypothesis in topology, measure theory and algebra will be discussed. Cofinality and inaccessible cardinals.

Model theoretic analysis of algebraic structures (4 ECTS – 20 hours)

Lecturer: P. D'Aquino (UniCampania)

We will present the main model theoretic techniques and tools in model theory as compactness, ultraproducts, elimination of quantifiers, model completeness, saturation, elimination of imaginaries. We will study the above properties in algebraically closed fields, real closed fields, valuation fields. Elimination of quantifiers implies a good understanding of the definable sets in a structure. Elimination of quantifiers for real closed fields gave birth to the notion o-minimality with applications in real algebraic geometry. We will analyze the fundamental result due to Ax-Kochen and Ershov on the transfer principle for valuation fields which translates properties of the field in terms of properties of the value group and the residue field.

Physics for Space Application (4 ECTS - 20 hours)

Lecturer: M. De Cesare (CIRA)

The course provides the basis of the experimental methodologies concerning the problems of measurement applications, diagnostic and theoretical-experimental characterization in aerospace application, typical of the re-entry phase (terrestrial and planetary). The need to qualify and measure on large on-ground laboratories for the development of modern diagnostic aerospace technologies is underline.

Research in mathematics education (4 ECTS - 20 hours)
Lecturer: U. Dello Iacono (UniCampania)

The course aims at supplying PhD students with the main theoretical frameworks in mathematics education and the main methodologies, by setting they in the historical context and in the national and international researches and by dealing the conceptual questions by an epistemological point of view.
In addition, the course aims to stimulate a critical analysis of the main teaching methodologies, also referring to the specific role of the teacher, to the conceptual, epistemological, linguistic and didactic aspects for the mathematics teaching and learning.
Teaching methods: multimedia lessons, laboratory activities, discussion of scientific papers.

Optics and Photonics for advanced multimodal metrology (4 ECTS - 20 hours)

Lecturer: P. Ferraro (CNR-ISASI)

Optical and photonic methods (interferometry, spectroscopy, holography, 3D imaging, IR, etc.) have the inherent advantage of being non-invasive, full-field and often based on image output. The course will address the fields of modern metrology based on optical and photonic approaches and methods for the characterization of materials, processes and components in the new paradigm of Industry 4.0. It will be given the groundwork for understanding the basic operating principles of the most advanced technology currently available for inspection and testing. Particular emphasis will be given to the interpretation and analysis of the measurements. Examples of applications in different fields (automotive, aerospace, cultural heritage, biotech, etc.) will be illustrated and discussed to understand the significant role of these methods today and in the next years considering the emerging “multimodal” approach in metrology. Finally will be discussed also the importance of exploiting Deep Learning in metrology connected to the aforementioned tools.

Stability analysis of open-channel flows with Newtonian and non-Newtonian fluids (4 ECTS - 20 hours)
Lecturer: M. Iervolino (UniCampania)

The course concerns the basic concepts of hydrodynamic instabilities, with application to a class of one-dimensional free surface flows which are encountered in both environmental and industrial applications. The governing equations for the one-dimensional free surface flow of thin layers are preliminarily discussed, with special reference to the rheological behavior of the considered fluid, i.e. Newtonian or non-Newtonian. Subsequently, the standard method of normal-mode analysis is applied to the investigation of the stability of the equilibrium flow of a thin-layer of fluid. The main features of unstable-free surface perturbations are evaluated based on the results of the normal mode analysis and their implication in practical applications is discussed. The theory of near-front wave expansion is then introduced to analysis the stability of flow influenced by the boundary conditions or the non-linear growth of the fronts of unstable perturbations, in a rather general framework that allows the application of this method to an even wider class of flows. In the last part of the course, PhD students are guided to the application of these techniques to examples from their own research field.

New Concepts and Materials for Applications in Electronics, Photovoltaics and Energy Storage (4 ECTS - 20 hours)

Lecturer: G. Landi (ENEA)

The course introduces:

- **new concepts and materials** for the next generation of **photovoltaics**: multijunction solar cells, multiple excitation solar cells, intermediate band solar cells and related technologies (for quantum dots, thin films, organic and perovskite).

- an **overview** of the latest advancements in **different types of batteries** (including rechargeable lithium and lithium-ion batteries, metal-air batteries) and supercapacitors with a comprehensive review of materials and technologies. Particular attention to environmentally friendly energy storage devices is given.

- **new biodegradable, polymeric and organic materials** that can be used as alternative systems to the inorganic materials for biodegradable/transient **electronics applications** (which can physically disappear after a period of stable operation with harmless end products).

Biophotonics for clinics and environment (4 ECTS - 20 hours)

Lecturer: M. Lepore (UniCampania) - I. Delfino (Università della Tuscia)

The course will deal with the application of optical techniques to the development of new diagnostic strategies and environment monitoring tools. Vibrational and fluorescence spectroscopies will be used for investigating biofluids, human tissues, radioesposed cells and enzymes in order to monitor biological processes and to develop sensor devices.

Stochastic Processes and Analysis of Correlations (4 ECTS - 16 hours)
Lecturers: E. Lippiello (UniCampania) – A. Sarracino

The purpose of these lectures is to give a simple mathematical introduction to the description of stochastic processes with innovative applications in the field of epidemiology and earthquake data time- series analysis.

<u>Syllabus</u>

Markov processes. Master and Fokker Plank equations. Stochastic energetics. Branching processes. Watson-Galtonmodel. Application to genetics. Epidemic models. Applications to epidemiology and earthquake occurrence. Analysis of correlations in stochastic signals. Detrended Fluctuation Analysis. Power spectrum of a signal.

Biophysical mechanisms and therapeutic implications of human exposure to ionising radiation (4 ECTS - 20 hours)
Lecturer: L. Manti (Università di Napoli Federico II)

Human exposure to ionizing radiation (IR), as a result of both naturally occurring sources as well as from diagnostic and therapeutic applications, is ubiquitous and entails well-known risks along evident benefits. The aim of the course is to provide the basic knowledge of the mechanisms that govern the biological action of IR, starting from the strong link between the patterns with which energy is deposited within the biological target and the consequences these might have at cellular, tissutal and organismal level. In fact, IR is unique among all the mutagenic and carcinogenic agents because it gives rise to a peculiar distribution of ionization clusters at the nanometer level, whose spatio-temporal proximity determines the severity of the damage incurred by the most important macrobiomolecule, the DNA. A cascade of complex pathway is then triggered that process such damage, driving the cell towards restoration of its genomic integrity or to death by several modes or, towards transmission of heritable damage. The latter is the most hazardous scenario for long-term effects such as cancer onset. The course will then illustrate the main biophysical models currently describing and quantifying the biological action of IR and the experimental work that has allowed to lay the foundations for modern radiotherapy (RT), such as the concepts of dose fractionation, together with novel phenomena that have questioned the central dogma of DNA as the sole target of radiation action. Special attention will be also devoted to illustrate the most advanced frontiers of novel radiation-based strategies to improve cancer control and minimize damage to the ineludibly exposed normal tissue, thereby reducing the risk of secondary cancers. Specifically, hadrontherapy (the use of accelerated particle beams), FLASH-RT, laser-driven particle acceleration, and radioimmunotherapy and the exploitation of nuclear physics reactions to locally enhance the effectiveness of external particle therapy will be discussed.

Navier-Stokes equations: an introduction to the well(ill)-posed initial boundary value problem (4 ECTS – 20 hours)
Lecturer: P. Maremonti (UniCampania)

The non-stationary Navier-Stokes equations are a model for the dynamic of a Newtonian incompressible viscous fluid. This model is considered suitable in some applicative fields. The model arises to avoid some mathematical paradoxes that we meet with the Euler model of ideal fluids. In two dimensional domains the mathematical theory can be considered sufficiently achieved. One proves not only that the PDE-problem is well-posed, but one achieves results also for some special phenomena, for example: time periodic motions under the action of time periodic forces, steady motions with reasonable physical conditions. Instead, the mathematical theory for the tridimensional model is unsatisfactory, one cannot say if the PDE-problem is well-posed or not. Many efforts in the last fifty years are made in a sense and in other sense with no concrete result.

The aim of the course is two-fold. From one side, we give the mathematical results in the two-dimensional case, pointing out the difficulties that one meets trying to extend the results in 3D. In particular in 3D we prove how in the case of "small data" everything works and, with methods of the energy, how it is possible to formulate and to find results of stability and attractivity of some steady motions. From another side, we just state the attempts devoted in proving the ill-posedness of the model.

Digital Signal Processing (4 ECTS - 20 hours)
Lecturers: S. Marrone (UniCampania) – L. Verde (Unicampania)

Signal processing is a well-assessed discipline whose objective is to provide unifying methods to analyse and manipulate analog and digital signals as they are produced/consumed by systems. By studying these methods, the students are able to apply them in different domains: from biomedical to astrophysics, enabling the application of advanced filtering and processing stages as AI-based stages.

The signal processing course as the objective to introduce Ph.D. students to the theory and to provide practical methods for the analysis and the manipulation of digital signals. The course is structured to pursue three objectives.

- Introduction to the concept of the digital signals.
- The definition of practical algorithms for the manipulation of signals.
- Concrete definitions of the MATLAB tool suite for implementing the proposed algorithms.

The course will focus, in particular, on the signals and Simulink toolboxes. Students will be called to use these toolboxes to implement simple case studied of digital signal processing workflows.

Petri Nets and their applications in science and engineering (4 ECTS - 20 hours)
Lecturer: S. Marrone (UniCampania)

Petri Nets is a formal language introduced in 1962 in the PhD thesis of Carl Adam Petri. Starting from this date, they proved their capability of modelling both discrete and continuous systems, being able to create a wide scientific literature, a meaningful set of industrial applications and the consequent releasing of a huge number of tools for their modelling and analysis.
Using Petri Nets, it is possible not only to obtain qualitative information on the modelled system as liveness, presence of deadlock and stability but also to get quantitative information as the probability of staying into a particular state of the system.
Up to now, Petri Nets are an assessed modelling formalism that can be used by the scientists to model the system under their study. Since their introduction, different variants and dialects of such a formalism have been introduced to raise the expressive power and to ease the modelling task.
Among such derived formalisms: the Generalized Stochastic Petri Nets (where activities can cost stochastically distributed times), the Fluid Stochastic Petri Nets (where resources can be continuous as well as discrete) and the Stochastic Well-formed Nets (adding “colours” to the tokens).
The objective of the course is twofold. On one hand, it introduces such this formalism since its mathematical foundations showing both the syntax and the semantics of the language as well as the main methods for the qualitative and quantitative analysis. On the other hand, it fills the gap between theory and practice of the application showing pragmatic application cases of the formalism in different aspects of science and engineering: from the security of computer-based systems to performance of industrial plants, to the modelling of continuous physical phenomena.

Isotope Physics and Methodologies (4 ECTS - 20 hours)

Lecturer: F. Marzaioli (UniCampania)

The course “Isotope Physics and Methodologies (IPM)” will be developed onto a 24 hours pathway. During the course the most important issues regarding the isotope sciences will be covered. In details, among the others, the most important issues such as i) a general overview of the isotope nomenclature for both stable and radioactive nuclides; ii) the most important isotope fractionation mechanisms; iii) the approaches and methodologies utilized to address research issues will be covered with a special emphasis onto Accelerator based Mass Spectrometry and data reduction/analysis. Opportunities of Laboratory experience(s) will also be planned aiming to apply acquired knowledge.

Astrophysics with ultra-high-energy neutrinos and Neutrino Telescope (2 ECTS - 8 hours)

Lecturer: P. Migliozzi (INFN)

Meson production, atmospheric neutrinos, the discovery of high-energy neutrinos, Sources of astrophysical neutrinos, Cosmic neutrino flux estimates, Neutrino detection principle and event topologies, The need for km3 neutrino telescopes, Water and ice properties, Operating neutrino telescopes, Results from neutrino telescopes.

Computational solid and structure mechanics: Finite elements and Boundary elements (4 ECTS - 20 hours)

Lecturer: V. Minutolo (UniCampania)

The noun structure designates the objects that in nature are responsible for bearing loads; every object, in a sense, is a structure even if some object has the structural ability as its main characteristic and other does not. For instance, bones of vertebrates, beams, and rods in machines and buildings are eminently structures. The Earth's surface, a mountain slope, the skin, and a blood vessel behave as structures when they are called to support loads even if their principal duty is somewhat else.

The course deals with the computational formulation of the mechanics of solids and structures.

After a brief introduction on the mechanics of structures within the framework of the continuum mechanics, the discretization techniques with finite elements are described. First, the one-dimensional problem is treated; furthermore, two and three-dimensional description f the structure is afforded.

The fundamentals of the variational approach and Galerkin formulation are addressed.

Betti reciprocal theorem constitutes the base of the Boundary Element formulation for linearly elastic structures. The feasibility of the method with respect to the two-dimensional and the three-dimensional structures is highlighted. The property of self-adjointness of the elastic equilibrium operator is described as the principal protagonist of the derivation of the Boundary Integral Equations of linear elasticity. Moreover, the extension of the formulation to non-linear elasticity, anisotropy, and plasticity is addressed.

Several examples using Matlab coding are discussed and implemented.

The application of linear elasticity, limit analysis of structures, fracture mechanics, and elastic instability form the core of the course.

Numerical Applications for Physics and Engineering (4 ECTS - 20 hours)

Lecturer: B. Morrone (UniCampania)

Many physical phenomena are described by using different mathematical models. “Model” is a set of equations and/or other mathematical relationships able to capture the patterns of the events and then describe, forecast and control them. General laws and constitutive relationships are the main pillars of the mathematical models. In industrial activities mathematical modelling has become largely widespread, followed by analysis and numerical simulation. Ordinary (ODEs) as well as partial differential equations (PDEs) result from the applications of models in the Engineering and Physics fields. The course gives a glimpse of the most employed numerical methods for solving either ODEs or PDEs, focusing also on the way they are implemented. Massive use of Matlab® is accomplished to test the different methods and their programming methods during the course interactively and several examples using Matlab coding are discussed and implemented.

<u>Syllabus</u>

• Short introduction to floating-point numerical type, significant digits, round errors and Taylor series. Introduction to Matlab programming.

• Ordinary differential equations. Introduction and motivations. Explicit and implicit Euler’s method, Runge-Kutta methods, predictor-corrector method. Truncation errors. Examples for physics and engineering applications. Initial Value Problems (IVP) vs. Boundary Value Problems (BVP).

• Partial Differential equations: classification, physical examples and their meaning. Well-posedness. Steady and transient problems. Parabolic and elliptic equations. Finite difference methods and Finite Volume methods to solve PDEs. Stability problems for numerical methods of parabolic equations. Accuracy of the numerical solutions. Examples for physics and engineering applications.

• Numerical methods for solving linear systems of equations using iterative methods (Jacobi, GaussSiedel, SOR, SSOR).

An introduction to Reaction-Diffusion Equations (4 ECTS – 20 hours)

Lecturer: B. Pellacci (UniCampania)

Reaction-Diffusion equations (RDEs) constitute a widely used tool to model phenomena arising in applied sciences such as physics, biology or sociology.
The description of the diffusion of individuals in an ecosystem, or of genes in a population, to mention just a few examples, naturally leads to partial-differential equations (PDEs), which may include reaction terms (transformation, source, internal interactions) as well as diffusion.
The main goal of the course will be to settle down a mathematical background on the classical initial-boundary value problems; then give a glimpse to some contemporary research lines in this field.

<u>Syllabus</u>

0. Introduction: examples, models and motivations.
1. Mathematical background and study of the initial boundary value problem.
1.1 Basic stuff on functional analysis, Sobolev spaces and eigenvalues.
1.2. Initial value problem: well-posedness both in bounded and unbounded domains; maximum and comparison principles.
1.3. Stationary solutions: existence, multiplicity, qualitative behavior; stability issues, principal eigenvalues.
1.4. Long-time behavior: convergence to equilibria, survival vs extinction.
2. A glimpse on contemporary research topics.
2.1. Optimization and shape optimization problems: optimal design of a habitat; best dispersal strategy.
2.3. Different diffusions, fractional derivative in time, cooperative and competitive systems.

Combinatorics and its applications (4 ECTS - 20 hours)

Lecturer: O. Polverino - F. Zullo (UniCampania)

Combinatorics is a branch of Mathematics of increasing importance, owing to its links with Information Theory, Statistics and other areas of Mathematics, such as Algebra and Geometry. This course will be a gentle introduction to the classical combinatorics and the new trends in Galois geometry, then focusing on some new recent aspects and some applications to Coding Theory and to Cryptography.

The topics covered by the course will be the following:

- Partially ordered sets (Sperner's Theorem, LYM inequalities. Bollobás's theorem. Dilworth's theorem)
- Extremal set theory (Theorems of Baranyai, Erdos-de Bruijn and Erdos-Ko-Rado)

- Linear algebra methods in combinatorics (The polynomial method and applications, Fisher's theorem, Equiangular lines, sets with few differences)
- Linear sets (Projection of subgeometries, Geometric and Algebraic field of linearity)
- Blocking sets (linear and non linear, Rédei type, nuclei of pointsets)
- Applications (Coding Theory and Cryptography)

Numerical methods for inverse imaging problems and parameter identification (4 ECTS – 20 hours)

Lecturer: M. Pragliola (Università degli Studi di Napoli Federico II) – G. Toraldo (UniCampania)

In this course, we will discuss variational models for the general image reconstruction problems where highly parametrized regularization terms are coupled with a fidelity term accounting for the noise degradation model. A particular attention will be thus given to the parameter identification problem, reviewing classical and more recent strategies. Popular algorithms for the solution of the resulting minimization problems, such as Alternating Direction Method of Multipliers (ADMM), will be discussed. Besides the theoretical lessons, the course will also include practical sessions.

Statistical Methods in Experimental Sciences (4 ECTS - 20 hours)

Lecturer: F. Terrasi (UniCampania)

The course aims at providing the students with a deep understanding of the basic grounds of statistical methods used in the analysis of experimental data, allowing them to identify the most adequate to the problem under study and to correctly interpret the statistical meaning of the results of their application.

Syllabus

- The results of an experiment as samples of statistical populations
- Multidimensional statistical variables. Change of variables; correlation.
- Statistical estimators: bias; efficiency.
- Maximum likelihood estimators.
- Hypothesis testing
- Least squares. Linear and non linear fits.