Educational program 2020/21

PhD Program in Mathematics, Physics and Applications to Engineering

XXXVI cycle

Courses (4 ECTS)

Interdisciplinary courses

Patent as an inventive research activity (24 hours)
Lecturer: A. Capece (UniCampania)

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

English Language (to be defined)

Introduction to modern computing infrastructures (24 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 Science: an Algorithmic Approach (16 hours)
Lecturer: E. Somersalo (Case Western Reserve University Cleveland, OH USA)

In order to extract pertinent information out of the enormous amount ofdata that are currently available, it is necessary to use sophisticated computational tools that are developed to reduce, visualize or otherwise compressthe data in a form that is understandable to humans. This course focuseson a number of fundamental principles and algorithms that are widely usedin modern data science, from analyzing scientific data to feature extractionfrom text and image data.
Rather than discussing ready-made black box algorithm packages, theemphasis of this course is on understanding the basic ideas behind the algo-rithms, as well as on the implementation of them from those first principles.The topics include data reduction and visualization, clustering, classificationalgorithms, text document analysis, texture analysis of images. Methodolog-ically, the course is built mostly on basic linear algebraic methods and doesnot require a background in statistics. It provides the tools for the stu-dents to build the algorithms from scratch. The algorithms discussed inthis course include principal component analysis (PCA), linear discriminantanalysis (LDA), k-means and k-medoids, tree-based classification methods,support vector machine (SVM), self-organizing maps (SOM), query match-ing and page ranking. Extensive numerical examples using real world datasets are discussed during the course. The programming language is Matlab.

Specialistic courses

Python Programming Fundamentals - Basics of Deep Learning and Neural Networks in Python (24 hours)

Lecturers: E.Bellini (UniCampania) - F. Marulli (UniCampania)

Module 1 (12 hours): Python Programming Basic

The objective of this module is to provide to the PhD students an initial set of knowledge of the Python 3 programming language. The course will have a pragmatic cut focusing on the practical use of Python as a tool in research rather than discovering the internal mechanisms of this language. This notwithstanding, the course will present the "pythonic" way of programming, i.e. the use of specific Python features that allow the ease construction of complex programs.

The course will also present libraries and packages devoted to the scientific computing (e.g., NumPy).

Module 2 (12 hours): Basics of Deep Learning and Neural Networks in Python

Deep learning represents the machine learning technique actually behind lots of exciting capabilities in several areas like robotics, natural language processing, image recognition, and artificial intelligence, including the famous AlphaGo. In this course, ph.D. students will gain hands-on, practical knowledge of how to use deep learning with very useful and popular Python based frameworks, as Tensorflow and Keras. This latter represents the latest version of a cutting-edge library for deep learning in Python.

Prerequisites:

Attendants should previously be able to program into a procedural programming language (e.g., C, Fortran) and computer architecture basics.

Syllabus:

1. Introduction to machine learning and deep learning
2. Introduction to Neural Networks and Deep Neural Networks
3. Comparing neural network models to classical regression models
4. Activation functions: The Rectified Linear Activation Function
5. Applying the network to many observations/rows of data
6. Deeper networks and Multi-layer neural networks
7. Forward propagation in a deeper network
8. Creating a model in Keras
9. Preparing data set
10. Choosing and compiling a model
11. Fitting and tuning a model
12. Classification models
13. Understanding results from classification.

Spline models for regression analysis (24 hours)

Lecturer: R. Campagna (UniCampania)

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. In particular, smoothing spline functions are a powerful tool in the regression model framework, to model and predict data trends.

The course aims at providing an introduction to basic smoothing spline models, including polynomials, thin-plate splines, 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.

<u>Syllabus</u>

1. Motivating applications
   - Signal and image processing
   - Computer graphics
   - Geometric deep learning and neural networks
2. Preliminaries
   - Spline functions
   - Parametric and nonparametric regression
   - Polynomial splines
   - Interpolating splines
3. Spline bases
   - Truncated power basis
   - B-splines
   - Radial basis functions
4. Smoothing spline regression
   - Smoothing splines
   - Regression splines
   - Penalized regression splines
5. Smoothing parameter selection and inference
   - Impact of the smoothing parameter
   - Trade-offs
   - Cross-validation and generalized cross-validation

Applications of Kinetic Theory to Non-mechanical Systems (24 hours)

Lecturer: B. Carbonaro (UniCampania)

Origin, motivation and meaning of the Boltzmann Equation - Generalization of the Boltzmann Equation to probability density function on non-mechanical variables: Vlasov equation - The case of continuous Variables - The case of discrete variables – Interaction rates and transition probabilities - Well-posedness problems - Stability and instability of solutions.

Theory of nuclear forces (20 hours)
Lecturer: L. Coraggio (INFN)

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.

Model theoretic analysis of Exponential fields (20 hours)
Lecturers: P. D'Aquino (UniCampania) - G. Terzo (Università di Napoli Federico II)

The main two examples of exponential fields are (R,exp) and (C,exp), the real and the complex fields with classical exponentiation. The theory of (R,exp) has been completely understood, while the theory of (C,exp) is still under investigation. A conjecture of Zilber on a possible axiomatization of (C,exp) goes back to early 2000. The aim of the course is to explain Zilber's conjecture and to illustrate the main results obtained in this area.

Physics for Space Application (24 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 (24 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.

Introduction to Partial Differential Equations and Calculus of Variations (20 hours)

Lecturers: G. Di Blasio (UniCampania) - G. Pisante (UniCampania)

The course aims to introduce some of the aspects of the wide world of Partial differential equations. The course is divided into two parts.

<u>Modulo I – PDEs</u>

Partial differential equations are often used to construct models of the most basic theories underlying physics and engineering. Our goal in this course is to give a brief introduction to this field. We first focus our attention on the solvability of uniformly elliptic second-order PDE and we give the notion of weak solutions. To this end, using the well-known Lebesgue spaces, we introduce the Sobolev spaces and their properties. The basic Hilbert space theory will allow us to study the existence and the regularity of weak solutions to the boundary value problem of elliptic PDE.

<u>Modulo II – Calculus of Variations</u>

The theory of Calculus of Variation enables us to study a quite important class of nonlinear PDEs, namely the ones having a variational structure, using relatively simple techniques from nonlinear functional analysis. The basic idea is to recast the problem of solving a PDE in terms of the existence of minimizers of a related abstract functional and subsequently to study the minimization problem. The course aims to present the main ideas underlying this theory mainly focusing on the existence and regularity results for minimizers of integral functionals defined in Sobolev Spaces.

<u>Syllabus</u>

<u>Modulo I – PDEs</u>

1. Introduction to partial differential equations: weak derivatives and properties, Sobolev spaces, Sobolev inequalities.
2. Compactness.
3. Existence and regularity of weak solutions.
4. Maximum principles.
5. Eigenvalues of symmetric elliptic operators and notes on eigenvalues of nonsymmetric elliptic operators.

Modulo II – Calculus of Variations

1. Introduction to basic ideas on Calculus of Variations: Integral functionals, first variation and Euler-Lagrange equations, second variation.
2. Existence of minima: coercivity, semicontinuity, convexity, polyconvexity.
3. An overview on the regularity properties of minimizers.
4. Constrained problems.

Advanced constitutive and structural models, and shape and topology optimization strategies (24 hours)
Lecturer: L. Esposito (UniCampania)

The course aims to provide students with the essential tools for modeling and computational analysis in the thermo-mechanical field of continuum and structures, and optimization strategies used in mechanics. By recalling continuum mechanics and fundamentals of modeling based on the Finite Element Method (FEM), the objective of the course is to illustrate the main approaches to modeling and numerical strategies for determining stress and strain in one, two, and three-dimensional structures, also considering examples of materials that exhibit geometrical and/or constitutive nonlinearities, in steady-state or transient regime.

Finally, the optimization strategies used in mechanics will be illustrated and implemented.

Syllabus:
-Reviews of continuum mechanics (equilibrium equations and kinematic models of continuum; constitutive equations; variational problem and discrete form of partial differential equations in elasticity; matrix analysis of reticular structures; the displacements approach; formulation of the minimum potential energy problem in the FEM; elastic analysis; high order and isoparametric elements; non-linear materials).

-Applications to one, two, and three-dimensional systems by means of FEM codes.

-Numerical simulations in ANSYS Multiphisics environment: 1) pre-processing phase: geometrical modeling; setting of the constitutive properties of the materials; choice of the finite element and discretization of the model (mesh); initial and boundary conditions settings; 2) solution phase: choice of the solver; 3) post-processing phase: analysis of the results.

-Ansys Parametric Design Language (APDL) programming language: the batch mode in ANSYS Multiphisics environment.

-Mechanical optimization strategies: design optimization; topological optimization; custom-made optimization. Applications.

Label free phase contrast microscopy: principles and applications - P. Ferraro, S. Grilli, L. Miccio, P. Memmolo **(24 hours)**
Lecturers: P.Ferraro (ISASI) - S. Grilli (ISASI)

Label-free microscopy techniques exploiting quantitative phase-contrast paradigm will be presented. In particular the methods based on interferometry and digital holography will be treated extensively. Physical principles will be reviewed and great attention will be given on the more efficient experimental arrangements and the most upgraded image processing procedures. The main feature of interferometric methods stands in the quantitative evaluation of the phase shift introduced in the wavefront due to the presence of sample. This is the reason of the great range of applications of such techniques from macroscopic length scale to microscopic world. The course will be mainly focused on microscopy and, in particular, on recent developments in bio-medical field.

Micro-manipulation of fluids by electro-hydrodynamic techniques - S. Grilli, P. Ferraro, R. Rega, S. Coppola, V. Vespini **(24 hours)**

Lecturers: P. Ferraro (ISASI) - S. Grilli (ISASI)

The manipulation of viscous fluids is of fundamental importance in different fields ranging from inkjet printing up to three-dimensional lithography. Different techniques are available nowadays that, basically, make use of spinnable polymer solutions pulled out form appropriate nozzle systems. This course will give information about the state of the art of these widespread techniques and will focus the attention to the recent advancements in the last decade where electric fields have been introduced for spinning and printing viscous fluids.

Laser Spectroscopy (20hours)
Lecturer: L. Gianfrani (UniCampania)

The aim of the course is to provide a complete overview of the most advanced methods of atomic and molecular spectroscopy that are currently used for fundamental studies and applied research. The course covers a wide range of quantum processes and optical phenomena, also describing the principle of operation of the most common laser sources, such as semiconductor diode lasers and quantum cascade lasers. In addition, it provides an introduction to line shape theory and nonlinear processes of radiation-matter interaction.

Stability analysis of open-channel flows with Newtonian and non-Newtonian fluids (24 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.

Continuous Model Theory and Contemporary Applications (20 hours)
Lecturer: Jose Iovino (University of Texas at San Antonio)

The course will be organized as follows:

1. Introduction to continuous first order logic and continuous model theory.
2. Ultraproducts and non standard analysis. Model theory of metric structures
3. Applications of model theory to functional analysis and to machine learning.

New Concepts and Materials for Applications in Electronics, Photovoltaics and Energy Storage (24 hours)
Lecturer: G. Landi (Università di Salerno)

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** in the latest advancements in **different types of batteries** (including rechargeable lithium and lithium-ion batteries, metal-air batteries, and electrochemical capacitors) and gives a comprehensive overview of materials and technologies.

- **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 (24 hours)

Lecturer: M. Lepore (UniCampania)

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.

Numerical Methods for Data Analysis in Optical Spectroscopy (24 hours)

Lecturers: M. Lepore (UniCampania) - I. Delfino (Università della Tuscia) - C. Camerlingo (CNR)

The course aims to introduce numerical methods particularly useful for the analysis of spectral data with particular attention to background subtraction, noise reduction and quantitative applications (chemometrics). Univariate and multivariate analysis (PCA, Principal Component Analysis), wavelet algorithms will be discussed and applied in the analysis of practical cases of students' interest.

Biophysical mechanisms and therapeutic implications of human exposure to ionising radiation (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 acceleratiorn, and radioimmunotherapy and the exploitation of nuclear physics reactions to locally enhance the effectiveness of external particle therapy will be discussed.

Petri Nets and their applications in science and engineering (24 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 (24 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.

Principle of non-Newtonian Fluid Mechanics (20 hours)

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

Solid and Structural mechanics (20 hours)

Lecturer: V. Minutolo (UniCampania)

The course aims to deal with the formulation of the mechanics of solids and structures starting from linear theories to arrive at the description of non-linear models by constitutive law and by effect of the non-infinitesimal part of the deformation. For this purpose, the main basic concepts of the linear theory of strain and stress are recalled and the conservative constitutive laws and related energies are introduced. The concept of constitutive law is then extended to non-linear behaviors such as damage and plasticity and anisotropic elastic behaviors are described. The formulation is generalized through the definition of variational principles such as those of total potential energy, complementary energy, and the functionals of Hellinger Reissner and Hu Washizu.

Main topics of the lectures are:

Basic deformation of 3D solid and two and one dimensional structures, strain, stress, balance equations. The formulation is proposed under small displacement and large displacement hypothesis.

Virtual work principle as a variational formulation.

Constitutive models, elasticity, iperelasticity, elastic potential, elastic complementary potential, isotropy, anisotropy, linear elasticity.

Energy functionals.

- Total potential energy
- Total complementary energy
- Hellinger Reissner

- Hu-Washizu

Variational formulations in ‘damage’, plasticity, and elastic stability; fundamentals for the approximation of solution.

Numerical Methods for Physics and Engineering (24 hours)

Lecturer: B. Morrone (UniCampania)

Scientists and engineers investigate the physical world. The measurement and tracking of every value of every variable in the real world is an impossible task. Consequently, they use different models for the physical world, which track every natural phenomenon, considered to be important for the given task to some desired level of accuracy. This implies that different professionals will work using different models, while describing the same physical world.

Since many problems to cope with are very difficult to solve analytically or would require loads of computations, the numerical methods come to help us representing an invaluable assistance for scientists. In addition, the problem given should be solved in the most efficient manner. If the solution is less efficient than another, there is a price to pay for this inefficiency.

This course will focus on Numerical methods, and the algorithms presented in this course are also evaluated in terms of efficiency.

Numerical methods are a set of mathematical modelling tools each of which allows to solve a specific type of problem. Massive use of Matlab or Octave programmes is accomplished to test the different methods and their programming methods during the course interactively.

<u>Syllabus:</u>

- Short introduction to floating-point numerical type, significant digits, round errors and Taylor series. Introduction to Matlab/Octave programs.
- Function interpolation and data set approximation. Lagrange interpolation, Newton method. Least square method for experimental data. Numerical examples.
- Equations and non-linear Root Finding methods: bisection, false position, secant method. Newton-Raphson method.
- Numerical integration: Trapezoidal rule. Simpson’s rule. Gaussian Quadrature. Short note on adaptive Integration
- Ordinary differential equations. Introduction and motivations. Euler’s method explicit and implicit, Runge-Kutta methods, predictor-corrector method. Examples for engineering applications. Initial Value Problems (IVP) vs. Boundary Value Problems (BVP).

Cohomological Methods in Group Theory (20 hours)
Lecturer: A. Russo (UniCampania)

One of the most important topic in Group Theory is the *Extension Theory*. Roughly speaking the object of extension theory is to show how a group can be constructed from a normal subgroup and its quotient. In this subject concepts from homological algebra (in particular, the first and the second cohomology groups) arise naturally and contribute greatly to our understanding of it. The classical theory of group extensions was developed by *O. Holder* (1895) and *O. Schreier* (1926) while the homological implications of the theory were first recognized by *S. Eilenberg* and *S. MacLane* (1947). The aim of the course is to give an introduction to this topic. Moreover, some applications to finite groups (as the famous splitting theorem of *Schur-Zassenhaus*) and to isomorphisms of groups will be investigated.

Lectures on Elasticity (20 hours)

Lecturer: A. Tartaglione (UniCampania)

The course aims to introduce the participants to the analysis of the properties of the solutions of the PDEs governing the deformations of the elastic bodies with infinite size. The interest lies in the huge quantity of applications the theory refers to, as the wave propagation phenomena, the scattering theory, the deformations of bodies with defects, etc.

After a brief overview on the basics of the theory of linear elasticity, the differential system of elastodynamics will be analysed, exploring the possibility to extend to unbounded domains the classical properties of the solutions (work and energy theorem, Graffi's reciprocity relation, uniqueness for the initial-boundary value problems, etc.). The need to make hypotheses on the material properties of the body, i.e., on the density and on the elasticity tensor representing the material response function, will be clear.

The differential system of elastostatics governing the equilibrium of unbounded elastic bodies will be also analysed. The problem of existence and uniqueness for different boundary value problems will be investigated, in relation to more or less stringent hypotheses on the elasticity tensor and to different regularity requests on the data.

Quantum nanodevices: fundamentals, nanofabrication and applications (24 hours)
Lecturers: A. Vettoliere - C. Granata - B. Ruggiero (ISASI)

Direct current Superconducting QUantum Interference Device (dc SQUID) is the most sensitive magnetic flux and field detector known so far. Due to the low operating temperature and the quantum working principle, a SQUID exhibits an equivalent energy sensitivity that approaches the quantum limit. In this course, the topic of nano-SQUID will be addressed. Starting from the underlying principles, the main characteristics on these quantum devices will be highlighted. The many configurations and arrangements will be also addressed together with the motivations, the theoretical aspects and the fabrication techniques. An overview of many nanoscale applications including the investigation of the magnetic properties of nanoparticles, magnetic molecules, cold atom clouds, nanowires or single electronic spin will be given.

Algebraic curves over finite fields and related codes (24 hours)

Lecturer: G. Zini (UniCampania)

This course intends to give an introduction to the theory of algebraic curves defined over a finite field and their applications in Coding Theory. The course will introduce all the basic algebraic and geometric notions which are necessary in the study of algebraic curves over an arbitrary field, and will focus on some aspects which are particular of algebraic curves over a finite fields. This theory will be then applied to the study of so-called Algebraic-Geometry codes, whose parameters will be investigated in relation with the properties of the underlying algebraic curves. Explicit examples of AG codes from concrete remarkable curves will be provided.