PHD COURSES 2019/2020

Algebra (A)

- Group theoretical approach for symmetric encryption
  Speakers: Aragona-Civino, 10 hours
  Program: Gruppi di permutazione ed in particolare gruppi primitivi, accenno alla classificazione dei gruppi primitivi finiti di O'Nan-Scott, crittografia simmetrica e cifrari a blocchi, gruppi generati dalle funzioni di cifratura di un crittosistema simmetrico, attacchi algebrici su cifrari a blocchi, attacchi di imprimitività, studio del gruppo G(SPN) generato dalle funzioni di cifratura di un SPN, condizioni per cui G(SPN) sia primitivo e condizioni per cui G(SPN) sia l'alterno.

Continuum Mechanics (CM)

- Variational derivation of continuum mechanics equations: 10 hours
  Speakers: Dell'Isola-Placidi-Barchiesi
  Program: The aim of this short course is to introduce the students to the variational methods that are used in continuum mechanics. Static and dynamic cases will be analyzed. The mathematical derivations will be done on the basis of assumptions that are formulated on the form of the action functional. In the static case, the action is reduced to the total energy functional and a method to derive its form from a discrete model is also sketched.

  Arguments: The subjects developed during the course will be a suitable selection of the following ones: 3D continuum elasto-dynamic model derivations for the standard and for the strain gradient case. Euler-Bernoulli beam theory derived from an Action principle as well as from a discrete model. Continuum equations for materials with band gap for the 3D and for the 1D cases. The choice may depend on the interests of the students.

  MODELS: Standard and strain gradient elastic materials. Euler beams. Materials with band gap.

  METHODS: Variational methods. Heuristic homogenization procedure.

  Tentative program:

  LECTURE 1: It is shown in details the case of 3D continuum elasto-dynamic case for the standard.
  LECTURE 2: It is shown in details the case of 3D continuum elasto-dynamic case for the strain gradient case.
  LECTURE 3: Standard Euler-Bernoulli beam theory will be derived from an action.
  LECTURE 4: Standard Euler-Bernoulli beam theory will be derived from a discrete model.
  LECTURE 5: The derivation of the continuum equations for materials with band gap for the 3D and for the 1D cases will be shown.

  Bibliography:

  [1] dell'Isola Francesco, PLACIDI L (2011). Variational principles are a powerful tool also for formulating field theories. In: F. DELL'ISOLA, S. GAVRILYUK. (a cura di): F. DELL'ISOLA, S. GAVRILYUK, CISM Courses and Lectures. Variational Models and Methods in Solid and Fluid Mechanics. CISM INTERNATIONAL CENTRE FOR MECHANICAL SCIENCES **535**, 1–16

  [2] Auffray, N.; dell'Isola, F.; Eremeyev, V.; Madeo, A.; Placidi, L.; Rosi, G. Least action principle for second gradient continua and capillary fluids: a Lagrangian approach following Piola's point of view. The complete works of Gabrio Piola. Vol. I, 1–89, Adv. Struct. Mater. **38**

  [3] El Sherbiny Mohammed, Placidi L (2018). Discrete and continuous aspects of some metamaterial elastic structures with band gaps. ARCHIVE OF APPLIED MECHANICS, vol. 18, p. 1725-1742

  [4] Placidi, L., dell'Isola, F., Barchiesi, E. (2020). Heuristic Homogenization of Euler and Pantographic Beams. In Mechanics of Fibrous Materials and Applications (123–155). Springer, Cham.

Dynamical Systems (DS)

- Perturbation Methods for Nonlinear Dynamical Systems : 6 hours
  Speakers: D'Annibale-Zulli
  Program: The course introduces the basics of the perturbation analysis for weakly nonlinear dynamical systems, with special reference to the multiple scale method for ordinary differential systems. The following topics are addressed: eigenvalue and eigenvector sensitivity analysis; initial value problems: straightforward expansions; the multiple scale method: basic aspects and advanced topics; Duffing oscillator under external excitation: primary, super-harmonic and sub-harmonic resonances; Duffing oscillator under parametric excitation; multi-d.o.f. quasi-Hamiltonian systems under external/parametric/internal resonances.

Geometry (G)

- Introduction to the Inverse mean curvature flow
  Speaker: Pipoli, 10 hours
  Program: In recent decades, the geometric flows have been a central topic in Geometric Analysis. They produced many important results and applications, for example, in the geometry of hypersurfaces and general relativity. The Inverse mean curvature flow (IMCF for short) is the prototype of the expanding flows. The main goal of this course is to introduce the IMCF with particular emphasis on how the geometry of the ambient manifold influences the evolution. We will focus on a series of results about the evolution of star-shaped hypersurfaces. Starting from the classical result by Gerhardt and Urbas where the ambient manifold is the Euclidean space, we will move to other ambient manifolds. Particular attention will be given to the case of the non-compact rank one symmetric spaces, i.e. the real, complex and quaternionic hyperbolic spaces. We will see that in each of the three cases new non-trivial phenomena occur.

Mathematical Analysis (MA)

- Divergence-free and divergence-controlled positive symmetric tensors. Applications to mathematical physics
  Speaker: Denis Serre (UMPA-ENS Lyon), March 2020, 16-18 hours
  Attività finanziata dall'**INdAM - Istituto Nazionale di Alta Matematica**

  Program: We present a new aspect of functional analysis, where the objects are positive semi-definite symmetric tensors, whose row-wise divergence either vanishes or takes values in bounded measures. Qualitatively, the determinant has an unexpected integrability property. Quantitatively, the corresponding integral obeys a sharp estimate. This is a versatile tool, which has application in several domains in mathematics or mathematical physics.

  For instance, we recover the isoperimetric inequality, and we have a new characterization of minimal surfaces. We shall investigate at depth applications to gas dynamics at every level of description: macroscopic (Euler equations), mesoscopic (Boltzmann) and microscopic (molecular dynamics). We shall also present applications to plasmas (Vlasov-Poisson) and explain why the tool is not suitable for viscous fluids (Navier-Stokes) and for the dynamics of galaxies; the fact is that the positivity of the tensor occurs when the force at stake is repulsive.

- Relative entropy methods in conservation laws
  Speaker: Lattanzio, 6 hours
  Program: The aim of this course is to introduce the relative entropy technique for conservation laws, both for strong and for weak solutions. After a review of the notion of weak, entropic solution for systems of conservation laws, we shall present the notion of relative entropy and how it is useful for establishing stability results in the aforementioned context. As a particular application of this method, we shall then investigate the convergence of (diffusive) relaxation limits.

Mathematical Physics (MP)

- Selected topics in kinetic theory of gases
  Speaker: Colangeli, 10 hours
  Program: The course will cover a selection of topics of classical kinetic theory of gases: phase space and Lioville's theorem; hard spheres and mean free path; BBGKY hierarchy; Boltzmann equation for hard spheres; Non-cutoff potentials and grazing collisions; Fokker-Planck equation; H-theorem and irreversibility; Chapman-Enskog expansion; Kac ring model.

  Bibliography: Carlo Cercignani, The Boltzmann Equation and Its Applications, Springer (1988)

Numerical Analysis (NA)

- Advanced Numerical Analysis
  Speaker: D'Ambrosio, 6 hours
  Program: Modern Numerical Analysis is not only devoted to accurately approximating the solutions to various problems through efficient and robust schemes, but also to retaining qualitative properties of the continuous problem over long times. Sometimes such conservation properties naturally characterize the numerical schemes, while in more complex situations preservation issues have to be conveyed into the numerical approximations. Moving along this direction, the course is focused on the so-called *geometric numerical integration* of differential problems. Topics: symplectic integrators for Hamiltonian problems, Benettin-Giorgilli theorem, long-term stability properties; accuracy analysis, Butcher theory of order via rooted trees; multivalue numerical methods, G-symplecticity, time-reversal symmetry.

  Suggested monograph: E. Hairer, C. Lubich, G. Wanner, *Geometric Numerical Integration*, Springer (2006)

Probability (P1 and P2)

- Probabilistic models for opinion dynamics (P1): 6 hours
  Speaker: Minelli
  Program:

- Random Dimers (P2): 6 hours
  Speaker: Gabrielli
  Program: Given a graph, a dimer covering or perfect matching is a subset of edges that cover each vertex exactly once. We will introduce combinatorial and probabilistic problems related to this construction. We will restrict to the planar and bipartite case giving an introduction to Kasteleyn theory.

  The lectures are based on R. Kenyon *lectures on dimers* and F.L. Toninelli *Lecture notes on the dimer model* and D. Cimasoni *The geometry of dimer models.*

Quantum Computing (QC)

- Introduction to Quantum Computing
  Speakers: Guidoni-Benfenati-Experts from IBM
  Program: The present course is a joint PhD course with the PhD in Informatics. The aim of the short course is to provide to students with background in mathematics and informatics the foundation of quantum computation. The course will consist of theoretical lectures as well as hands-on tutorial in a computer laboratory lead by the Quantum Computing experts from IBM-Italia.

Arguments: Introduction to Quantum Mechanics and Qubits. Quantum circuits and algorithms. Single and double Qubit gates with examples. Present and future applications. General overview on perspective of quantum computation and practical implementation of algorithms on the IBM-Q quantum computer and simulator.