SSM
Scuola Superiore Meridionale

Course title:

Numerical treatment of PDEs

Duration [number of hours]**: 24**

PhD Program [MERC/MPHS/SPACE]**: MPHS**

Name and Contact details of unit organizer(s):

Prof. Francesco Calabrò
Affiliation(s): Dipartimento di Matematica e Applicazioni "Renato Caccioppoli"
Website: https://www.docenti.unina.it/francesco.calabro
Email: Francesco.calabro@unina.it

Course Description [max 150 words]**:**

Aim of this course is to introduce the basic theory for the numerical approximation of partial differential equations. A review on existing methods is given, then focus is on the treatment of elliptic linear problems with the Finite Element Methods.
Also, some insights on the treatment of time derivatives for parabolic and hyperbolic problems is given. Matlab and FreeFem coding are introduced and used during all the course.

Syllabus [itemized list of course topics]**:**

- Introduction on PDEs and numerical approaches for the discretization. Abstract formulation. Hilbert spaces, Riesz representation theorem, Lax-Milgram
- Essential notions on Sobolev spaces. Variational formulation, Ritz-Galerkin method, Cea lemma. Weak formulation of elliptic problems: derivation of models, treatment of both essential and natural boundary conditions.
- Galerkin-Finite Elements Methods. Conformal methods, meshing, the choice of the finite element. The Lagrangian Elements on triangularizations.
- Interpolation error: definition of the interpolator; Deny-Lions theorem; related finite elements and reference element. Global estimate. Best approximation properties of Galerkin methods in the symmetric case: strain energy, potential energy, numerical stiffness, discrete eigenvalues.
- Error estimate in the Poisson case both in norm H^1 and L^2 (Aubin-Nitsche).
- The structure of a finite element code. Meshing and change of variables in the reference domain. Local construction and global assembly.
- Matrix description of Finite Element Method, quadrature issues. First Strang lemma and quadrature error analysis. Patch test for non-conformal approximations.
- Stokes Equation: saddle point formulation. Primal mixed and dual mixed methods for the Poisson equation. Existence of solutions. Mixed finite element methods: inf-sup condition for the Babuška–Brezzi theorem.
- An introduction to the Isogeometric method.

Assessment [form of assessment, e.g., final written/oral exam, solutions of problems during the course, final project to be handed-in, etc.]**:**

Projects will be proposed during the course, along with some insights from books or recent literature.

Suggested reading and online resources:

Suggested books:

1. S. Brenner & L. Scott “The Mathematical Theory of Finite Element Methods“, Springer 2008
2. A. Quarteroni ”Numerical models for differential problems “, Springer 2016
3. T. Hughes “The finite Element Method”, Dover 1987Book 2

Notes: https://www.mate.polimi.it/biblioteca/add/qmox/49-2013.pdf
Slides: https://freefem.org/

Course title:

Micromagnetics and Spintronics

Duration [number of hours]: **_12_**

PhD Program [MERC/MPHS/SPACE]: **__MPHS____**

Name and Contact details of unit organizer(s):

Prof. _________ Massimiliano d'Aquino__________
Affiliation(s): __Università degli Studi di Napoli Federico II_________________
Website: __http://wpage.unina.it/mdaquino/_________________
Email: _massimiliano.daquino[at]unina.it___________________

Course Description [max 150 words]**:**

Micromagnetics and Spintronics:
The Course contents include:
Phenomenology of ferromagnetic media
- Magnetic materials and Maxwell's equations
- Hysteresis loop
- Exchange interaction and spontaneous magnetization
- Magnetostatic dipole-dipole interactions and magnetic domains
- Anisotropy

Micromagnetic free energy and magnetization dynamics
- Micromagnetic free energy
- Brown's equations, micromagnetic Equilibria, nucleation and stability of equilibria
- Stoner-Wohlfarth model
- Gyromagnetic precession, Landau-Lifshitz (LL) and Landau-Lifshitz-Gilbert (LLG) equations
- Qualitative properties of magnetization dynamics.

Micromagnetic dynamics in uniformly magnetized nanomagnets and spintronic devices
- Introduction to Magnetic Recording, magnetization switching
- Ferromagnetic resonance
- Introduction to Spintronics: Giant Magneto-Resistive and Spin-Transfer-Torque effects.
- Spin-Transfer-Torque driven magnetization dynamics
- Magnetization self-oscillations and current-driven switching

Micromagnetic dynamics with spatially nonuniform configurations
- Numerical methods for the solution of LLG equation.
- General formulation of magnetization small oscillations problem in ferromagnets
- Small oscillations in the macrospin approximation
- Linear spin-waves
- Computations of spin-waves spectrum in confined structures.

A glimpse on selected more advanced topics in Micromagnetics and Spintronics
- Thermally-driven magnetization dynamics
- Elements of chaotic magnetization dynamics
- Topologically non-trivial configurations: vortex, Skyrmion
- Spin-transfer-torque driven vortex oscillators

Syllabus [itemized list of course topics]**:**

- Phenomenology of ferromagnetic media
- Micromagnetic free energy and magnetization dynamics
- Micromagnetic dynamics in uniformly magnetized nanomagnets and spintronic devices
- Micromagnetic dynamics with spatially nonuniform configurations
- A glimpse on selected more advanced topics in Micromagnetics and Spintronics

Assessment [form of assessment, e.g., final written/oral exam, solutions of problems during the course, final project to be handed-in, etc.]**:**

The assessment will be based on a final project that consists in writing a report on one of the topics of the course. The report is required to include numerical or analytical computations relevant to a specific problem in Micromagnetics and Spintronics.

Suggested reading and online resources:

Lecture Notes on specific topics of the course will be provided to students during the course.
Suggested books:

[1] W.F. Brown, Magnetostatic Principles in Ferromagnetism, North-Holland (1962)
[2] W.F. Brown, Micromagnetics, Robert E. Krieger, Publishing Company (1978)
[3] L.D. Landau, E.M. Lifshitz, Electrodynamics of Continuous Media, Pergamon (1984)
[4] A. Aharoni, Introduction to the Theory of Ferromagnetism, Clarendon Press (1996)
[5] G.Bertotti, I.D. Mayergoyz, C. Serpico, Nonlinear Magnetization Dynamics, Elsevier (2009)

SSM
Scuola Superiore Meridionale

Course title:

Partial Differential Equations

Duration: 24 hours

PhD Program: MPHS

Name and Contact details of unit organizer:

Dr. Martin Mayer
Affiliation: Scuola Superiore Meridionale
Email: m.mayer@ssmeridionale.it

Course Description:

The course is meant to be a basic introduction to Partial Differential Equations in the Euclidean setting by

- exposing key aspects of the classical linear theory
- exemplifying modern mathematical techniques to deal with non-linear equations
- providing, when necessary, relevant preliminaries from
  functional analysis and the calculus of variations,
  e.g. functional spaces, their properties or minimization arguments.

The course is addressed to any PhD Student with standard mathematical background from Bachelor's and Master's Degree in Science and Engineering.

Syllabus:

- linear partial differential equations:
  - first order
  - second order
  - elliptic and parabolic systems
- nonlinear partial differential equations:
  - Burger
  - Poisson
  - reaction-diffusion
  - wave with damping and source

Assessment:

Evaluation: Final assessment – the student explores one of the topics of the course, perhaps an equation close to the area of personal interest, and gives a seminar in an oral exam

Suggested reading and online resources:

Notes will be released after each lecture. Suggested books
* Evans: Partial Differential Equations
* Friedman: Partial Differential Equation of Parabolic Type

* Gilbarg, Trudinger: Elliptic Partial Differential Equations of Second Order