ALLEGATO 1.2

REGOLAMENTO DIDATTICO DEL CORSO DI STUDI MATHEMATICAL ENGINEERING

CLASSE LM-44

Scuola: SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

Dipartimento: DIPARTIMENTO DI MATEMATICA E APPLICAZIONI R. CACCIOPPOLI

Regolamento in vigore a partire dall'a.a. 23-24

PIANO DEGLI STUDI A.A. 23-24

LEGENDA

Tipologia di Attività Formativa (TAF):

B = Caratterizzanti
C = Affini o integrativi
D = Attività a scelta
E = Prova finale e conoscenze linguistiche
F = Ulteriori attività formative

Curriculum A

I Anno

Denominazione Insegnamento	SSD	Modulo	CFU	Ore	Tipologia Attività	TAF	Ambito disciplinare	obbligatorio /a scelta
Real and Functional Analysis	MAT/05	unico	9	72	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	Obbligatorio
Mathematical Physics Models	MAT/07	unico	9	72	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	Obbligatorio
Numerical Methods	MAT/08	unico	9	72	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	Obbligatorio
Thermodynamics and Transport Phenomena	ING-IND/22	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Nonlinear Systems	ING-INF/04	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Mathematical Methods for Engineering	MAT/05	unico	6	48	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	uno a scelta dal GRUPPO 1
Calculus of Variations	MAT/05	unico	6	48	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	
Stochastic Processes	MAT/06	unico	6	48	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	
Operational Research	MAT/09	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Algebraic Structures and Advanced Linear Algebra	MAT/02	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Mathematics for Cryptography	INF/01	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Algorithms and Parallel Computing	INF/01	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Statistical Methods and Signal Theory	SECS-S/02	Modulo 1: Statistical Methods for Industrial Process Monitoring	6	48	Lezione frontale	C	Discipline economiche e statistiche/ingegneristiche	uno a scelta dal GRUPPO 3
	ING-INF/03	Modulo 2: Signal theory	6	48	Lezione frontale	C		
Statistical Methods and Economic Theory	SECS-S/02	Modulo 1: Statistical Methods for Industrial Process Monitoring	6	48	Lezione frontale	C	Discipline economiche e statistiche	
	SECS-S/06	Modulo 2: Economic theory	6	48	Lezione frontale	C		
Modern and Solid State Physics	FIS/01	Modulo 1: Modern Physics	6	48	Lezione frontale	C	Discipline matematiche, fisiche, informatiche	
	FIS/03	Modulo 2: Solid State Physics	6	48	Lezione frontale	C		

II Anno

Computational Fluid Dynamics	ING-IND/06	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Electrodynamics of continuous media	ING-IND/31	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Optoelectronics	ING-INF/01	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	uno a scelta dal GRUPPO 2
Electromagnetic Fields	ING-INF/02	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Information Theory	ING-INF/05	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Systems Identification	ING-INF/04	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
A scelta autonoma			12			D		
Ulteriori Conoscenze			3			F		
Prova finale			18			E		

Curriculum B

I Anno

Denominazione Insegnamento	SSD	Modulo	CFU	Ore	Tipologia Attività	TAF	Ambito disciplinare	obbligatorio /a scelta
Real and Functional Analysis	MAT/05	unico	9	72	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	Obbligatorio
Mathematical Physics Models	MAT/07	unico	9	72	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	Obbligatorio
Numerical Methods	MAT/08	unico	9	72	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	Obbligatorio
Thermodynamics and Transport Phenomena	ING-IND/22	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Nonlinear Systems	ING-INF/04	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Differential Geometry	MAT/03	unico	6	48	Lezione frontale/MOOC	B	Discipline matematiche, fisiche, informatiche	uno a scelta dal GRUPPO 1
Discrete Mathematics	MAT/02	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Partial Differential Equations	MAT/05	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Advanced Applied Engineering Mathematics	MAT/07	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Computational Complexity	INF/01	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Geometric Structures and Topology	MAT/03	unico	6	48	Lezione frontale	B	Discipline matematiche, fisiche, informatiche	
Statistical Methods and Chemical Process	SECS-S/02	Modulo 1: Statistical Methods for Industrial Process Monitoring	6	48	Lezione frontale	C	Discipline economiche e statistiche/ingegneristiche	uno a scelta dal GRUPPO 3
	ING-IND/26	Modulo 2: Chemical Process Analysis and Simulation	6	48	Lezione frontale	C		
Statistical Methods and Economic Theory	SECS-S/02	Modulo 1: Statistical Methods for Industrial Process Monitoring	6	48	Lezione frontale	C	Discipline economiche e statistiche	
	SECS-S/06	Modulo 2: Economic theory	6	48	Lezione frontale	C		
Modern and Solid State Physics	FIS/01	Modulo 1: Modern Physics	6	48	Lezione frontale	C	Discipline matematiche, fisiche, informatiche	
	FIS/03	Modulo 2: Solid State Physics	6	48	Lezione frontale	C		

II Anno

Computational Fluid Dynamics	ING-IND/06	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Electrodynamics of continuous media	ING-IND/31	unico	9	72	Lezione frontale	B	Discipline ingegneristiche	Obbligatorio
Mechanical Vibrations	ING-IND/13	unico	6	48	Lezione frontale/MOOC	B	Discipline ingegneristiche	uno a scelta dal GRUPPO 2
Electromagnetic Fields	ING-INF/02	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Waves	ING-IND/06	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Heat Transfer	ING-IND/10	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Analysis and Control of Complex Systems	ING-INF/04	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Nonlinear Dynamics and Control	ING-INF/04	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Environment Fluid Mechanics and Hydraulics	ICAR/01	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
Theory of Elasticity	ICAR/08	unico	6	48	Lezione frontale	B	Discipline ingegneristiche	
A scelta autonoma			12			D		
Ulteriori Conoscenze			3			F		
Prova finale			18			E		

ALLEGATO 2

REGOLAMENTO DIDATTICO DEL CORSO DI STUDI MATHEMATICAL ENGINEERING

CLASSE LM-44

Scuola: SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

Dipartimento: DIPARTIMENTO DI MATEMATICA E APPLICAZIONI R. CACCIOPPOLI

Regolamento in vigore a partire dall'a.a. 23-24

Insegnamento: ADVANCED APPLIED ENGINEERING MATHEMATICS	
SSD: MAT/07	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction to mathematical modelling for Engineering. The course presents diffusion models, wave motion models, steady-state models, Euler-Bernoully model for beams, Finite Difference Method and Finite Element Method for Partial Differential Equations.	
Obiettivi formativi: Introduction to mathematical modelling for Engineering. The course presents diffusion models, wave motion models, steady-state models, Euler-Bernoully model for beams, Finite Difference Method and Finite Element Method for Partial Differential Equations.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: ALGEBRAIC STRUCTURES AND ADVANCED LINEAR ALGEBRA	
SSD: MAT/02	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Symmetric bilinear and hermitian forms. Diagonalization of symmetric bilinear forms and Gaussthm. Sylvester's theorem. Tensor products of vector spaces. Symmetric tensors. Orthonormal bases and Gram- Schmidt process. Normal matrices. Spectral theorem. Projectors and spectral decomposition of Normal matrices. Hadamard's inequality. Gram matrices. Singular Value Decomposition. Matrix norms. Spectral norm. Exponential of a matrix. Dynamic mode decomposition of a linear system. Polar decomposition and Classical groups. LU, Choleski and QR factorizations.	
Obiettivi formativi: To provide students with a good understanding of the concepts and methods of advanced linear algebra aimed at solving engineering problems.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: ALGORITHMS AND PARALLEL COMPUTING	
SSD: INF/01	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Classification and main functional characteristics of the parallel architectures. Parallel Algorithms Performance Evaluation Parameters. Methodologies to design and develop parallel algorithms and their strong dependency by the hardware/software architectures. Performance Evaluation and Scalability of parallel algorithms. Math model for analyzing parallel algorithms Load Balancing. Fault and Latency tolerant algorithms. Programming models and paradigms: cluster computing, multicore computing, network computing, GPU computing. The present cases of grid and cloud computing. Implementation of several algorithms in distributed and shared memory environments: examples of matrix computation and array sorting algorithms. Use of tools for message passing and for shared memory.	
Obiettivi formativi: To deal with the basic ideas, methodologies, tools and software to design and develop algorithms in High Performance Parallel/Distributed Computing Environments. The Lab practice plays a key role in this one-semester course.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Lab tests during the course; final written/oral test.	

Insegnamento: ANALYSIS AND CONTROL OF COMPLEX SYSTEMS	
SSD: ING-INF/04	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction to complex systems and networks. Elements of graph theory and macroscopic observable of a network system. Networked dynamical systems: emerging properties. Consensus and Synchronization in Complex Networks. Stability and Convergence of network systems: the master stability function approach; contraction theory and incremental stability; Lyapunov based approaches. Observability and Controllability of a complex network. Centralized, decentralized and distributed control of complex systems. Adaptive control of networks. Applications to Engineering.	
Obiettivi formativi: This course aims at introducing students to the key theoretical and numerical tools for the analysis and control of complex systems and networks of interconnected dynamical systems. The theoretical concepts will be illustrated via a set of representative examples from Engineering and Applied Science.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination and project work.	

Insegnamento: CALCULUS OF VARIATIONS	
SSD: MAT/05	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B 3 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction to Calculus of Variations, classical problems and examples. Function spaces. Weak and strong minimizers. Frèchet and Gâteaux differentiation. Fundamental lemma, DuBois-Reymond lemma, one-dimensional Euler-Lagrange equations. Problems with free ends, piecewise functions and minimization. Erdmann-Weierstrass equations. Regularity of solutions.One-dimensional Poincaré and Wirtinger inequalities. Second Euler-Lagrange and Erdmann-Weierstrass equations. Minimization with constraints. Geodesics on surfaces. Hamiltonian formulation. Hamilton-Jacobi equations. Optimal control problems and examples. Pontryagin principle.Convex functionals. Jacobi and Weierstrass conditions. Excess. Legendre condition. Second variation of a functional. Lipschitz minimizers and regularity. Absolutely continuous minimizers and regularity. Existence and regularity of minimizers of one-dimensional problems. Multidimensional problems. Dirichlet functional and harmonic functions. Euler equations in the multidimensional case. Dirichlet functional: existence, uniqueness and regularity of minimizers. Poincaré inequalities. Isoperimetric problems. Worked examples.	
Obiettivi formativi: The course aims to provide a basic knowledge of Calculus of Variations with particular focus on the application to optimization methods for engineering and scientific problems.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: COMPUTATIONAL COMPLEXITY	
SSD: INF/01	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Problems and algorithms: intuitive formulations and their formalizations through multi-string Turing Machines and languages. Appropriate measures of space and time requirements. Speedup theorems. Comparison with other formalizations of computations and Church's thesis. Complexity classes, hierarchy theorems, and Savitch's theorem. Reductions and completeness (respectively) as formalizations of the relative difficulty and characteristic complexity of problems. NP-complete and coNP-complete graph and set problems. Cook's theorems. The polynomial hierarchy and PSPACE. Relationships with modern cryptography. A glimpse beyond PSPACE: problems that need exponential resources and undecidable problems.	
Obiettivi formativi: This course is the ideal complement of a course in algorithmics. It provides an in-depth knowledge of the inherent complexity of problems and the resources needed to solve them with algorithms. As such, it provides criteria for assessing the optimality of algorithms. The course expands on the relationships between memory and time requirements, and on the role of nondeterminism in assessing the difficulty of problems whose complexity is not exactly known. This part has important links with cryptography, operational research, and combinatorial optimization.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination.	

Insegnamento: COMPUTATIONAL FLUID DYNAMICS	
SSD: ING-IND/06	**CFU:** 9
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: The Finite-Difference method for partial differential equations. Applications to model differential equations describing steady and unsteady convection-diffusion transport phenomena. Methods for the numerical solution of ordinary differential equations. Writing of numerical codes for the simulation of 1D and 2D spatial-temporal linear transport equations and comparison with analytical solutions. Numerical solution of the Navier-Stokes (NS) equations for incompressible flows: projection methods. Numerical treatment of convective terms in incompressible NS equations using finite-difference and finite-volume methods. Analysis of the conservation properties of the discretizations. Vorticity-streamfunction and Harlow-Welch methods and their generalizations. Outline of high-order and spectral methods.	
Obiettivi formativi: The aim of the course is to provide students with the theoretical foundations of numerical discretization of fluid flow equations, as well as to permit them to understand and apply the basic techniques of modern Computational Fluid Dynamics.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Written text on a case study and oral examination.	

Insegnamento: DIFFERENTIAL GEOMETRY	
SSD: MAT/03	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B 3 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: The exact program will be decided during the course, depending on the interests and background of the students. It will be a subset of the following topics: - Charts and atlases, smooth structures, topology induced by an atlas, smooth manifolds. Smooth maps. Tangent and cotangent vectors. Tangent map. Vector bundles, local frames. The tangent bundle, vector fields. Tensors and tensor fields. Differential forms. De Rham cohomology. Integration. - Lie groups (definition and examples). Matrix groups, a few elementary results: the exponential map, Lie algebra, closed-subgroups theorem. - (Pseudo-)Riemannian manifolds. Existence of Riemannian structures. Gradiend, divergence, rotor, laplacian. Divergence theorem and Green identities. Connections on vector bundles, geodesics and parallel transport. The geodesic field. The exponential map. Levi-Civita connection and Koszul formula. Riemannian geodesics and Riemannian distance. The Riemann and Ricci tensors, scalar curvature, Weyl tensor. Conformally flat manifolds. Sectional curvature. Manifolds with constant sectional curvature. A glance at Killing-Hopf and Cartan-Hadamard theorems. - Symplectic and Poisson manifolds.	
Obiettivi formativi: The aim is to provide students with a good understanding of the concepts and methods of differential geometry.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: DISCRETE MATHEMATICS	
SSD: MAT/02	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: The course will be accomplished through different topics. First of all the basic concepts and therminology of the Set Theory will be introduced; in particular, the use of Mathematical induction will be relevant. Moreover, the arithmetic properties of the integer numbers and the modular arithmetic will be presented, and the most relevant properties of the following structures will be illustrated: groups, finite fields, polynomials rings. Also the basic concepts of Linear Algebra will be introduced.	
Obiettivi formativi: The aim of the course is to introduce students to mathematical ideas and techniques that will be useful in different types of applications. In particular, students will learn the basic algebraic concepts and terminology, so that they will be able how to use and analyse recursive definitions, and to work inside some different types of discrete structures. Moreover, they will learn techniques for constructing mathematical proofs, with the support of various examples.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: ELECTRODYNAMICS OF CONTINUOUS MEDIA	
SSD: ING/IND-31	**CFU:** 9
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction to electromagnetism and Maxwell equations. Electrodynamics potentials. Radiation of a point dipole and general aspect of radiation. Maxwell-Lorentz model and relation between microscopic and macroscopic electromagnetism. Elements of special relativity. Conductive materials. Elements of Magneto-Hydro Dynamics (MHD). Dieletric materials and Electrostatics. Introduction to circuit theory. Magnetic Materials, Magnetostatics, Electromechanics. Elements of Micromagnetic Theory. Mathematical methods.	
Obiettivi formativi: The aim of the course is to attain a general understanding of Classical Electrodynamics with a special attention to the mathematical aspects of the theory. A central theme in the course is the description, within the continuum approach, of the interactions of electromagnetic fields and material media.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral interview.	

Insegnamento: ELECTROMAGNETIC FIELDS		
SSD: ING-INF/02		**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B	
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Engineering and Electromagnetic Fields. Maxwell's equations in integral and differential form, the inductive approach, physics as semantic for electromagnetic fields, energy and electromagnetic fields. Deductive approach, mathematics as syntax of electromagnetic fields, from Maxwell equations to the theorems, validity limits and meanings. Engineering and representations of electromagnetic fields in the various domains: time, phasor, frequency and wave number domain. Constitutive relations: models, formulation and meaning. Canonical solutions for the various domains. Source free solutions: propagation. Solutions in the presence of sources: Green's method, radiation. Role of initial conditions, integral-differential formulations and their solution. Role of the boundary conditions; geometry and symmetry (planar, circular, spherical) for canonical problems in electromagnetic fields. Applications and techniques: cavity, waveguides, transmission lines. Ideal and actual boundary conditions: perturbative approaches to solutions. Engineering parameters and paradigms for propagation. Engineering parameters and paradigms for radiation. Deterministic and stochastic approaches to the solution of electromagnetic field problems in engineering. Approximate solutions to the propagation and radiation. Asymptotic and series expansion solutions: method, validity, meaning, applications. Solutions in engineering of electromagnetic field problems: methods, validity, reliability.		
Course aims: The course introduces Engineering and Mathematical Engineering paradigms to support comprehension and exploitation of Electromagnetic Fields. Theory, techniques, methods, algorithms and engineering applications are presented.		
Propedeuticità in ingresso: **Propedeuticità in uscita:**		
Tipologia degli esami e delle altre prove di verifica del profitto: Oral interview and discussion.		

Insegnamento: ENVIRONMENT FLUID DYNAMICS AND HYDRAULICS		
SSD: ICAR/01		**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B	
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Mass and momentum conservation equations. Transition from laminar to turbulent conditions. Time and phase averages. Reynolds equations. Balance of the kinetic energy of the averaged field. Balance of the turbulent kinetic energy. Energy transfer among the velocity components. Wall turbulence. Turbulence models: algebraic and differential (with one and two equations) models. Introduction to the equations of unsteady water flow at different dimensionality (1D: de Saint-Venant equations, 2D: Shallow water equations), conservative and non conservative (classical) formulations. Characteristics method for the De Saint-Venant equations. Finite volume discretization of model equations. Implicit and explicit schemes. Riemann problems and approximate Riemann solvers for the numerical flux evaluation.		
Obiettivi formativi: The course will provide students with an introduction to the problem of the closure of fluid dynamic turbulence. Some models of zero, one and two equations will be illustrated. An application problem will be solved by using a commercial software for the numerical solution of the presented equations. The course will develop a comprehensive view of		

unsteady free surface flows of water, considered as an incompressible fluid, at a large scale (rivers, lakes) by recovering the fundamental equations in 1 and 2 spatial dimensions. Numerical solutions by finite volume and finite difference methods will be developed for 1D and 2D models.
Propedeuticità in ingresso: **Propedeuticità in uscita:**
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.

Insegnamento: GEOMETRIC STRUCTURES AND TOPOLOGY	
SSD: MAT/03	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Topological and metric structures. Compactness. Path connected spaces. Basic homotopy theory: deformations, retracts, homotopy equivalences. Fundamental group. Basic Homological Algebra. Singular homology groups.	
Obiettivi formativi: The course aims to provide basic knowledge in General and Algebraic Topology, especially to students with an unsatisfactory background in Geometry.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: HEAT TRANSFER	
SSD: ING-IND11	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Conduction: The governing equation. Steady one-dimensional heat conduction. Steady two-dimensional heat conduction. Analytical solutions. Transient conduction. Numerical methods. Convection: The governing equations for: mass, momentum and energy transport. Forced and natural convection: boundary layer; boundary layer equations; dimensionless parameters; analytical solutions; external and internal flow; correlations. Radiation: Introduction. Processes and characteristics. Characteristics of real surfaces. Diffuse and directional gray surface radiation heat transfer. Semi-transparent radiative media. Combined heat transfer mechanisms. Heat exchangers: Basics and definitions. Project equations.	
Obiettivi formativi: The course introduces basic concepts and principles of heat transfer. It covers analytical, empirical and numerical techniques for the solution of heat transfer problems. The aim of the course is to understand the fundamentals of heat transfer mechanisms and their applications in various heat transfer equipment.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination, project discussion.	

Insegnamento: INFORMATION THEORY	
SSD: ING-INF/05	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: The course explores the basic concepts of Information theory. Self information, mutual information, discrete memoryless sources, entropy, source coding for discrete memoryless channels. Data compression to the entropy limit. Huffman coding. Arithmetic coding. Discrete memoryless channels, channel capacity, converse to the coding theorem, noisy channel coding theorem, random coding exponent, Shannon limit. Gaussian channels. Kolmogorov complexity. Asymptotic equipartition property. Applications to communication and data compression.	
Obiettivi formativi: The field is at the intersection of mathematics, statistics, computer science. The course is highly recommend for students and researchers in fields of communications, data compression, and statistical signal processing. However it would be invaluable also for students, planning to delve into fields ranging from neuroscience, to machine learning. Students will acquire high familiarity with measures of information and uncertainty such as mutual information, entropy, and relative entropy. Students in probability and statistics will gain an appreciation for the interplay between information theory, combinatorics, probability, and statistics.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Written/oral examination.	

Insegnamento: MATHEMATICAL METHODS FOR ENGINEERING	
SSD: MAT/05	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B 3 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Complex number system. Functions of complex variable: holomorphic functions and Cauchy-Riemann conditions; harmonic functions. Taylor series expansions. Laurent series expansions. Residues. Difference equations. Introduction to measure theory; Lebesgue measure and integral. Fourier transform and inversion formula; properties of the transform, convolution. Fourier series, convergence theorems. Distributions. Laplace transform and inversion formula; properties of the transform, applications to differential models.	
Obiettivi formativi: To provide the fundamental concepts and results, in view of applications, related to the theory of analytic functions, distributions, Fourier series, Fourier and Laplace transforms and their applications.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination.	

Insegnamento: MATHEMATICAL PHYSICS MODELS	
SSD: MAT/07	**CFU:** 9
Anno di corso: I	**Tipologia di Attività Formativa:** B 6 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Degree of Freedom. D'Alembert Principle. Lagrange Equations. Hamilton. Equations. Variational Principles. Vector Spaces. Affine Euclidean Point Spaces. Tensor Algebra. Curvilinear Coordinates in Euclidean Spaces. Elements of Continuum Classical Mechanics.	
Obiettivi formativi: The course is an introduction to mathematical modeling of physical processes. The course presents Lagrange model of Mechanics, Tensor Calculus and elements of Continuum Mechanics.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: MATHEMATICS FOR CRYPTOGRAPHY	
SSD: INF/01	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Elementary Number Theory: notation and basic properties; divisibility and the Euclidean algorithm; congruences; modular arithmetic; basic arithmetic functions (the Euler totient function, the Moebius function); the Chinese Remainder Theorem with some applications; polynomial congruences modulo a prime number (the Lagrange Theorem); quadratic residues; the Legendre symbol; the Jacobi symbol; quadratic reciprocity law; finite fields Computational Number Theory: times estimates for doing elementary arithmetic; basic notions on computational complexity and classification of the algorithms; estimating the number of bit operations needed to perform some number theoretic tasks by computer, such as the Euclidean algorithm, the repeated squaring method and the Jacobi algorithm; the discrete logarithm problem; the distribution of prime numbers with applications to the computational complexity Primality: pseudoprimes (the Fermat pseudoprimes, the Euler pseudoprimes, the strong pseudoprimes); Carmichel numbers; primality test (Solovay-Strassen and Miller -Rabin); times estimates for primality tests Factoring: basic facts on the factoring problem; the Erathostenes method; the Fermat method; the Pollard method; smooth numbers; the quadratic sieve method; some notes on the Number Field Sieve. The arithmetic of the elliptic curves: basic facts on the elliptic curves; primality test; the Lenstra factorization method; the discrete logarithm problem on the elliptic curves. Cryptography: some simple cryptosystems; symmetric keys; public key cryptography; the Diffie-Helmann problem; the RSA protocol; elliptic curve cryptosystems; cryptanalysis.	
Obiettivi formativi: The purpose of the course is to introduce the student to number theoretic topics, both ancient and very modern, which are at the center of interest in contemporary cryptography, especially in the most known public key cryptosystems such as RSA; an algorithmic approach is taken, emphasizing estimates of the efficiency of the techniques that arise from the theory.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Written dissertation and oral colloquium.	

Insegnamento: MECHANICAL VIBRATIONS		
SSD: ING-IND/13		**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B 3 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)	
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Conservative and non-conservative lumped parameters systems: Technical relevance of the problem. Matrix equations of motion. Modal analysis method: free and forced vibrations by action of: harmonic, periodic and random forces. Considerations on damping proportional or not. Frequency response function. Dynamics of elastically suspended rigid body: Definition of the mathematical model. Determination of the matrices of the masses and stiffness. Discrete and continuous elements suspension systems. Determination of forcing actions. The vehicle suspensions: Requirements of a suspension system. Types of suspensions. The dynamics of the suspended mass with respect to the ride comfort. Simple and compensated air suspensions. Conjugate suspensions. Forced torsional oscillations: Historical Introduction to the study of torsional oscillations and technical relevance of the problem. Lumped system determination. Particular equivalent systems: system of naval propulsion and transmission system of a motor vehicle. Exciting causes of forced vibration. Critical speeds. Amplitudes of forced elastic vibrations for a system of n masses. Flexional vibrations and critical speed: Historical Introduction to the study of flexional vibrations and technical relevance of the problem. Simple system. Disk effect. Systems n concentrated masses, isostatic and statically indeterminate. Method of transfer matrix**.**		
Obiettivi formativi: The course intends to provide the necessary concepts for the identification, mathematical formulation, simulation and testing of the most significant dynamic phenomena in the field of machines and mechanical systems, with particular reference to the flexional critical speeds, torsional oscillations and the elastically constrained rigid body dynamics.		
Propedeuticità in ingresso: **Propedeuticità in uscita:**		
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.		

Insegnamento: MODERN AND SOLID STATE PHYSICS	
Modulo 1: MODERN PHYSICS	
SSD: FIS/01	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** C
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction to the "Special Relativity": The constancy of the speed of light and the Michelson - Moreley experiment. The Lorentz transformations. Consequences of special relativity: time dilation and length contraction. Introduction to the 4-vectors: the 4-velocity. Some notion of relativistic kinematics: the 4-momentum and the Einstein relation E=mc^2. The Lorentz group and the transformation properties of the electric and magnetic fields. Introduction to the quantum mechanics**:** The Black body radiation. The Rayleigh-Jeans law and the Plank hypothesis. Photoelectric and Compton effect. Rutherford's atomic model and the Bohr's hypothesis. The de Broglie hypothesis and the wave-particle duality. The Schroedinger equation. Some method of solution for the partial differential equations: the separation of the variables. Some applications of the Schroedinger equation: a free particle; a particle in an infinite well; the Heisenberg uncertainty principle; the mean value of the observables; the Ehrenfest's theorem; the potential barrier and the tunnel effect; the quantum oscillator; the hydrogen atom. A short introduction to the theory of General Relativity**:** From the equivalence principle to the Riemmanian manifolds. The Hilbert-Einstein equation. The weak field approximation: Newtonian mechanics, gravitational waves, the bending of light. The model of Friedmann-Lemaitre- Robertson-Walker The standard cosmological model. The Standard model of elementary particle physics (a very short overview) Open problem of Modern Physics.	
Obiettivi formativi: The course aims to provide an introduction to fundamental aspects of 20th century physics: special relativity, quantum mechanics, elementary particle physics, general relativity and cosmology.	
Modulo 2: SOLID STATE PHYSICS	
SSD: FIS/03	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** C
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Single particle electronic states in one-dimensional double and multiple quantum wells; Kroenig-Penney model; Bloch theorem in one dimension; Nearly free electron. Bravais Lattices in different dimensions; Reciprocal lattices and Brillouin zone; Bloch theorem in any dimension; Tight-binding method for electronic band structures; Electronic states of Graphene. One band model for metal; Two-band model for semiconductors; Thermodynamic properties of metals and intrinsic semiconductors. Hartree and Hartree-Fock approximation; Jellium model. Dielectric constant; Screening effects in metals; Dielectric properties of semiconductors; Impurities in metals and semiconductors; Chemical potential of extrinsic semicondutors. Vibrational degrees of freedom; Harmonic approximation for solids; Classical normal modes; Phonons; Thermodynamic properties due to phonons. Transport properties. Drude model for metals and semiconductors; Semiclassical dynamics and Boltzmann equation.	
Obiettivi formativi: Fundamental aspects of solid state physics. Phenomenological and microscopic description of metals and semiconductors. Transport, thermodynamic and dielectric properties of solids.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: NONLINEAR DYNAMICS AND CONTROL	
SSD: ING-INF/04	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Part 1 Introduction and background**:** Introduction, Elements of matrix theory. Part 2 Graph theory: Elements of graph theory, Linking graphs and matrices. Part 3 Analysis and control of networks of linear dynamical systems: consensus problem: Discrete-time consensus problem, Continuous-time consensus problem, Convergence rates, Consensus problems on time-varying graphs. Part 4 Networks of nonlinear dynamical systems: synchronization: Networks of nonlinear dynamical systems, Synchronization. Part 5 Control of networks of nonlinear dynamical systems: Decentralized control of network of nonlinear systems, Emerging problems and advanced network control techniques.	
Obiettivi formativi: The course aims at providing students with a set of tools for the analysis and control of networks of dynamical systems, with a special emphasis on their optimization and safety, and on their possible use for the design and management in diverse engineering applications.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: NONLINEAR SYSTEMS	
SSD: ING-INF/04	**CFU:** 9
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction: linear vs nonlinear systems; planar nonlinear systems: equilibria, limit cycles, phase portraits, existence of periodic orbits and bifurcations; Fundamental properties: well-posedness, continuous dependence on initial conditions; Lyapunov stability and applications; Nonlinear Dynamics and Bifurcation theory: local bifurcations of maps, local bifurcations of flows, introduction to global bifurcations and deterministic chaos; Perspectives on advanced topics in nonlinear systems: piecewise smooth systems, nonsmooth stability analysis.	
Obiettivi formativi: The aim of the course is to introduce students to the foundations of the mathematical theory of nonlinear systems of ODEs and to illustrate the theory via some representative examples from applications.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination and project discussion.	

Insegnamento: NUMERICAL METHODS	
SSD: MAT/08	**CFU:** 9
Anno di corso: I	**Tipologia di Attività Formativa:** B 6 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Numerical linear algebra: conditioning, error analysis, iterative and exact (factorization based) methods. Eigenproblems: basic numerical approaches. Interpolazione Lagrangian interpolation, splines, numerical quadrature. Differential operator discretization; their representation and solution by finite difference numerical approximations. Linear differential problems and application: Laplace and Poisson equations, FFTs, linear convection. General techniques for solving ordinary differential equations, like Runge-Kutta and linear multistep methods. Laboratory classwork and problem sets require some knowledge of problem solving environments (MATLAB, Python,…).	
Obiettivi formativi: The primary goal is to provide a basic knowledge of numerical methods, enabling students to work with mathematical models of technology and systems.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination, written test.	

Insegnamento: OPERATIONAL RESEARCH	
SSD: MAT/09	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction to Operational Research and Optimization. Linear Programming (LP): Introduction to LP and form of a LP problem; Geometry of continuous LP; The Simplex Method. Integer Linear Programming (ILP): Introduction to ILP; Linear Programming Relaxation; Special ILP problems with unimodular constraints matrix: the Transportation Problem, the Assignment Problem. Solution methods: Exact Methods: Branch &Bound; Cutting Planes, Dynamic Programming; Approximation Methods; Heuristic and Metaheuristic Methods; The 0/1 Knapsack Problem and the Fractional Knapsack Problem. Network flows and graph problems: The Minimum Vertex Cover Problem; The Minimum Spanning Tree Problem; Shortest Path Problems; Project Scheduling Problems: Critical Path Method (CPM); Path Evaluation and Review Technique (PERT); Post-optimization analysis. Nonlinear Optimization: Unconstrained Nonlinear Optimization: Optimality conditions; Gradient Methods: Convergence, Descent Directions and Stepsize Rules; Newton's Method and Variations; Least Squares Problems: the Gauss-Newton Method, Incremental Gradient Methods; Coniugate Direction Methods; Quasi-Newton Methods; Nonderivative Methods. Optimization over a Convex Set; Lagrange Multiplier Theory; Lagrange Multipier Algorithms.	
Obiettivi formativi: The main objective of the course is the introduction of the students to the use of mathematical programming models. Both linear and nonlinear optimization models (with both continuous and integer variables) are studied, and their applications in real-world fields, including communications, logistics, services, and industrial production. As concerns nonlinear programming models, the course aims at providing a comprehensive and rigorous treatment of classical topics, such as descent algorithms, Lagrange multiplier theory, and duality. In addition, some of the more sophisticated methods are also covered, such as interior point methods, penalty and barrier methods, least squares problems, and conditional gradient and subgradient optimization.	

Propedeuticità in ingresso: **Propedeuticità in uscita:**
Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination.

Insegnamento: OPTOELECTRONICS	
SSD: ING-INF/01	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: As optical microsystems continue to increase in functionality while decreasing in volume, integrated optics is becoming increasingly relevant for a wide spectrum of applications. In an integrated optical circuit, light is guided via optical waveguides, an approach which allows integration of numerous optical functions on a single semiconductor, glass or dielectric substrate. This course is designed to provide an overview of integrated optics, from the system point to view. The course will present the basic concepts of integrated optics, including materials and fabrication technologies as well as the major integrated optical devices.	
Obiettivi formativi: To provide the fundamental concepts and results, in view of applications, related to the theory of analytic functions, distributions, Fourier series, Fourier and Laplace transforms and their applications.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Student will be evaluated on the base of an original Elaboration and Discussion on a pre-assigned topic, and oral examination on the course contents.	

Insegnamento: PARTIAL DIFFERENTIAL EQUATIONS	
SSD: MAT/05	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Physical and probabilistic interpretation of the Laplacian. Laplace equation: fundamental solution and Newtonian potential. Harmonic functions: mean value theorem, maximum principle, Liouville theorem, Harnack inequality, Weyl lemma, analiticity of harmonic functions. Uniqueness of solutions of Dirichlet and Neumann problems. The Green function of a general domain. Explicit computation of the Green function in a half space and in a ball. Dirichlet principle for Poisson equation. The heat equation: fundamental solution, mean value theorem, maximum principle and regularity of solutions. Uniqueness and backward uniqueness. Energy methods. Transport equation. Wave equation. Explicit solutions of the wave equation in dimensions 1, 2 and 3. The characteristic cone and the finite speed propagation of the initial data. Energy methods. Separation of variables and explicit solutions of Poisson equation, heat equation and porous media equation. Fourier transform and its application to solve explicitly Poisson, heat and wave equations, Schrödinger equation and the telegraph equation. Laplace	

transform and applications. Sobolev functions: definition, basic properties, H=W, approximation by smooth functions, extension domains, traces, embedding and compact embedding theorems, Poincaré inequality. Weak solution of an elliptic equation. Existence of weak solutions, regularity. Compact operators. Fredholm alternative. Eigenvalues and spectrum of a linear operator. Eigenvalues and eigenfunctions of the Laplacian.

Obiettivi formativi: The first objective of the course is to provide the basic results on existence, uniqueness and qualitative properties of solutions of classical PDEs such as: Laplace, Poisson, heat, transport and wave equations;
the second objective is to give the basic tools for solving explicitly in special cases the above equations using variables separations, series expansion, Fourier or Laplace transforms; the third objective is to provide a thorough introduction to Sobolev functions with the aim of accomplishing the fourth objective of the course, that is an introduction to weak solutions of a linear elliptic equation in divergence form and the corresponding existence, uniqueness and nonuniqueness, and regularity results.

Propedeuticità in ingresso:
Propedeuticità in uscita:

Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.

Insegnamento: REAL AND FUNCTIONAL ANALYSIS	
SSD: MAT/05	**CFU:** 9
Anno di corso: I	**Tipologia di Attività Formativa:** B 6 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso:
Topological spaces. Metric spaces. Completeness**.** Compactness. Complete matric spaces: Banach spaces, Hilbert spaces. Orthonormal basis and Fouries series in Hilbert spaces. Linear and continuous operators between normed spaces. Compact operators. Adjoint operators. Spectral decomposition of self-adjoints operators. Spectrum of Laplace operator. Weak topologies. Reflexive spaces. Separable spaces. L^p spaces. Sobolev spaces and variational formulation of boundary value problems for partial differential equations. Introduction to Galerkin methods and finite elements methods in a model case.

Obiettivi formativi: The aim of this course is to provide students with basic knowledge of Real Analysis and Functional Analysis, particularly topics that are useful for the study of many other Mathematical Engineering courses.

Propedeuticità in ingresso:
Propedeuticità in uscita:

Tipologia degli esami e delle altre prove di verifica del profitto: Tests in itinere and/or oral examination.

Insegnamento: STATISTICAL METHODS AND CHEMICAL PROCESS

Modulo 1: STATISTICAL METHODS FOR INDUSTRIAL PROCESS MONITORING

SSD: SECS-S/02	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** C

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso:

Elements of classical Statistical Process Control: Control Charts for variables. Control Charts for attributes. Number of samples and sampling frequency. Sample size and control effectiveness. The Multivariate Quality-Control Problem: Overview and Learning Objectives. Description of Multivariate Data. Descriptive statistics and graphical displays. The geometry of a multivariate sample. Sample mean, covariance and correlation. Generalized variance and total variance. The metric induced by the covariance matrix. Data representation and dimensional reduction. The analysis of the covariance structure. Inference about mean vectors. The multivariate normal distribution, the Wishart distribution, the F distribution. Hotelling T2 test. Confidence regions and simultaneous comparisons of component means. The Bonferroni method for multiple comparisons. Family-wise Error Rate (FWER). Comparisons of several multivariate means. Inference for Linear Models.
Engineering approach to modern Process Monitoring and Control**.** The Hotelling T2 Control Chart. Latent Structure Methods. Engineering examples through software environment R. Introduction to functional data analysis and control charts for statistical monitoring of functional data. Functional data analysis. Statistical monitoring of functional data. Industrial case studies and applications.

Obiettivi formativi: Statistical Methods for Industrial Process Monitoring is a methodological –applicative course whose aim is to train students on statistical tools for monitoring complex technological systems. Application (illustrated through opensource statistical software environment R) of interpretable statistical techniques for decision-making, possibly scalable also up to big data frameworks. Teamwork on data-analysis projects developed along the course that are gathered from real-world industrial problems (problem-based learning). Students should improve the ability to recognize the most suitable mathematical space to immerge the data and statistical techniques to solve the problem at hand as well as the skill of communicating relevant results and the impact of the analysis also to non-statistician

Modulo 2: CHEMICAL PROCESS ANALYSIS AND SIMULATION

SSD: ING-IND/26	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** C

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Introduction to the methodological basis for the modelling of chemical processes of interest in industrial applications. Dynamics of Reaction in a non-isothermal CSTR: Stationary states, Oscillatory behaviour, Complex oscillations and chaos. Dynamics in Autocatalytic systems. Model characterization through computer simulations.

Obiettivi formativi: The course will focus on the mathematical description of chemical and physical phenomena that occur in the process industry equipments.

Propedeuticità in ingresso:
Propedeuticità in uscita:

Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination.

Insegnamento: STATISTICAL METHODS AND ECONOMIC THEORY

Modulo 1: STATISTICAL METHODS FOR INDUSTRIAL PROCESS MONITORING

SSD: SECS-S/02	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** C

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso:

Elements of classical Statistical Process Control: Control Charts for variables. Control Charts for attributes. Number of samples and sampling frequency. Sample size and control effectiveness. The Multivariate Quality-Control Problem: Overview and Learning Objectives. Description of Multivariate Data. Descriptive statistics and graphical displays. The geometry of a multivariate sample. Sample mean, covariance and correlation. Generalized variance and total variance. The metric induced by the covariance matrix. Data representation and dimensional reduction. The analysis of the covariance structure. Inference about mean vectors. The multivariate normal distribution, the Wishart distribution, the F distribution. Hotelling T2 test. Confidence regions and simultaneous comparisons of component means. The Bonferroni method for multiple comparisons. Family-wise Error Rate (FWER). Comparisons of several multivariate means. Inference for Linear Models.
Engineering approach to modern Process Monitoring and Control**.** The Hotelling T2 Control Chart. Latent Structure Methods. Engineering examples through software environment R. Introduction to functional data analysis and control charts for statistical monitoring of functional data. Functional data analysis. Statistical monitoring of functional data. Industrial case studies and applications.

Obiettivi formativi: Statistical Methods for Industrial Process Monitoring is a methodological –applicative course whose aim is to train students on statistical tools for monitoring complex technological systems. Application (illustrated through opensource statistical software environment R) of interpretable statistical techniques for decision-making, possibly scalable also up to big data frameworks. Teamwork on data-analysis projects developed along the course that are gathered from real-world industrial problems (problem-based learning). Students should improve the ability to recognize the most suitable mathematical space to immerge the data and statistical techniques to solve the problem at hand as well as the skill of communicating relevant results and the impact of the analysis also to non-statistician

Modulo 2: ECONOMIC THEORY

SSD: SECS-S/06	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** C

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Part I Mathematical techniques for equilibrium analysis: real analysis; metric spaces; topology; measures; convexity; separation theorems; contraction mapping; fixed point theorems; probability and information structures. Part II Applications to the study of existence and optimality properties of competitive equilibrium (CE): existence and efficiency of CE; core, value and fairness properties of CE; core, value and fairness properties of CE in asymmetric information economies; alternatives to the expected utility theory.

Obiettivi formativi: The course introduces students to a rigorous investigation of equilibrium concepts in microeconomic theory, including cooperative and non-cooperative solution concepts in general equilibrium models with uncertainty and asymmetric information.

Propedeuticità in ingresso:
Propedeuticità in uscita:

Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination.

Insegnamento: STATISTICAL METHODS AND SIGNALS THEORY

Modulo 1: STATISTICAL METHODS FOR INDUSTRIAL PROCESS MONITORING

SSD: SECS-S/02 | **CFU:** 6

Anno di corso: I | **Tipologia di Attività Formativa:** C

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso:

Elements of classical Statistical Process Control: Control Charts for variables. Control Charts for attributes. Number of samples and sampling frequency. Sample size and control effectiveness. The Multivariate Quality-Control Problem: Overview and Learning Objectives. Description of Multivariate Data. Descriptive statistics and graphical displays. The geometry of a multivariate sample. Sample mean, covariance and correlation. Generalized variance and total variance. The metric induced by the covariance matrix. Data representation and dimensional reduction. The analysis of the covariance structure. Inference about mean vectors. The multivariate normal distribution, the Wishart distribution, the F distribution. Hotelling T2 test. Confidence regions and simultaneous comparisons of component means. The Bonferroni method for multiple comparisons. Family-wise Error Rate (FWER). Comparisons of several multivariate means. Inference for Linear Models.
Engineering approach to modern Process Monitoring and Control**.** The Hotelling T2 Control Chart. Latent Structure Methods. Engineering examples through software environment R. Introduction to functional data analysis and control charts for statistical monitoring of functional data. Functional data analysis. Statistical monitoring of functional data. Industrial case studies and applications.

Obiettivi formativi: Statistical Methods for Industrial Process Monitoring is a methodological –applicative course whose aim is to train students on statistical tools for monitoring complex technological systems. Application (illustrated through opensource statistical software environment R) of interpretable statistical techniques for decision-making, possibly scalable also up to big data frameworks. Teamwork on data-analysis projects developed along the course that are gathered from real-world industrial problems (problem-based learning). Students should improve the ability to recognize the most suitable mathematical space to immerge the data and statistical techniques to solve the problem at hand as well as the skill of communicating relevant results and the impact of the analysis also to non-statistician

Modulo 2: SIGNALS THEORY

SSD: ING-INF/03 | **CFU:** 6

Anno di corso: I | **Tipologia di Attività Formativa:** C

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Basic concepts about probability and random variables. Characterization of continuous-time and discrete-time random signals in the time domain and in the frequency-domain. Representation of periodic signals. Representation of continuous-time and discrete-time signals in the frequency domain. Filtering in the time-domain and in the frequency domain. Digital processing of signals: basic concepts and implementation issues.

Obiettivi formativi: The aim of the course is to provide the basic tools for the analysis of deterministic signals and for their processing using linear systems, both in the time and frequency domain. A further goal is to introduce the basic concepts of probability theory and random processes.

Propedeuticità in ingresso:
Propedeuticità in uscita:

Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination.

Insegnamento: STOCHASTIC PROCESSES	
SSD: MAT/06	**CFU:** 6
Anno di corso: I	**Tipologia di Attività Formativa:** B 3 CFU in presence, 3 CFU MOOC (Massive Open Online Courses)
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Review of definitions and fundamental theorems of probability measure theory. Conditioned averages with numerous application examples. Stopping times. Martingales and convergence results. Examples. Brownian motion. Main laws of Brownian motion. Markov processes. Analytical approach to Brownian motion. Stochastic integration. Ito's formula and stochastic differential equations.	
Obiettivi formativi: The course intends to recover the basic knowledge of Probability theory (by making them more complete and rigorous) through the re-proposition, in a marked formalism, of fundamental contents. Concepts, contents and tools are provided, such as definitions, properties and theorems regarding conditional means, stopping times, martingale, Brownian motion, Markov processes and stochastic integration, which represent the basis both for a more in-depth study of the theory and for a conscious use in the applications of stochastic processes.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Written and oral examination.	

Insegnamento: SYSTEM IDENTIFICATION	
SSD: ING-INF/04	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Dynamical Optimization: Multi-stage optimization problems and dynamical constraints: definition and meaning of the objective function and solution of the problem using a variational approach. Adjoint system and necessary conditions for optimality. Optimal control problem for discrete-time systems. Multi-stage decision. The linear-quadratic (LQ) case. State-feedback solution and the Riccati equation. Solution of the LQ regulator in open and closed loop. Bellman's Principle of Optimality and Dynamic Programming (DP). Solution of the optimal control problem using the DP algorithm. Application to the LQ problem. Asymptotic solution of the optimal control problem and stability of the closed-loop system. Dynamical Optimization in Presence of Uncertainty: Brief overview on probability and statistics. Static optimization in presence of uncertainty: certainty equivalence and stochastic programming. Decisions in presence of uncertainty. Modeling uncertainty: measurement and process noises. White gaussian noise and noise propagation through a discrete-time dynamical system. Multi-stage decision problem in presence of uncertainty. Uncertain objective functions. The value of information on the state and closed-loop solutions. Solution of the linear-quadratic-gaussian (LQG) problem via DP. State Filtering and Prediction: State estimation in an uncertain linear dynamical system. Kalman predictor/corrector/filter. Filter optimality. The extended Kalman filter for nonlinear systems. Optimal control with estimated state feedback. Matlab/Simulink implementation of the state-feedback optimal control and of the asymptotic Kalman filter. Numerical examples in applications. Estimation Theory: *Parametric estimation.* Data generating process. Modeling uncertainty. Estimators and estimates. Properties of estimators. Least squares and Gauss-Markov estimates. Quality of the least squares estimate. Orthogonality between the estimate	

and the prediction error. Recursive least squares estimator. Issues in the numerical implementation. Forgetting factor in recursive least squares estimation. Minimum-variance unbiased estimator, and linear minimum-variance unbiased estimator. Maximum likelihood estimator. *Bayesian Estimation* The Bayesian estimation problem. Minimization of the conditional least squares. Properties of the Bayesian estimator. Bayesian estimator in presence of correlated information sources. Linear Bayesian estimator: properties. Kalman filter as Bayesian estimator. A priori prediction, correction and estimate update. Relation between recursive parametric estimation and optimal state filtering. Numerical application of estimation theory with Matlab/Simulink implementation. Identification Models for identification. Overview on the state-space and input-output representations of a dynamical systems. Polynomial representation using the *z*-operator. Model and equation errors. ARMAX models. Identification problem. Model and parameter identification. Model accuracy and complexity. Validation of the identified model and residuals analysis. Stochastic models of time series: AR, ARX, MA, ARMAX. Correlation analysis and spectral analysis. Predictions of times series models. Formulation of the parameter identification problems as a parameter estimation problem. Efficiency of least square estimates. Structural and experimental identifiability. Order estimation and model validation.

Obiettivi formativi: Providing both a theoretical and practical skills to apply optimization and identification tools to synthesize control systems for different kind of processes, with an emphasis on estimation and control in presence of uncertainty.

Propedeuticità in ingresso:
Propedeuticità in uscita:

Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.

Insegnamento: THEORY OF ELASTICITY	
SSD: ICAR/08	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B

Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Basic vector and tensor calculus: the index notation. Specialization of Continuum Mechanics equations to linear elastic solids: compatibility, equilibrium, linear elastic constitutive behavior. Weak and strong forms for structural problems: the principle of virtual displacements - theoretical formulation and mechanical interpretation. Equations of elastic equilibrium of one-, two- and three-dimensional elements. Modeling of structural problems by finite element analysis: modeling of geometry (meshing), material, loads and restraints. Solving procedures and rendering of results by professional software.

Obiettivi formativi: The main objective of the course is to make the students get acquainted with the general concepts of continuum mechanics and to operatively apply them for the solution of basic problems in linear elasticity. The principal topics dealt with are: Tensor analysis, infinitesimale and finite deformations; Lagrangian and Eulerian strain measures. Mechanical balance laws: Cauchy continuum and stress measures. Constitutive laws. Principle of material frame indifference. Variational techniques and finite element method.

Propedeuticità in ingresso:
Propedeuticità in uscita:

Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.

Insegnamento: THERMODYNAMICS AND TRANSPORT PHENOMENA	
SSD: ING-IND/22	**CFU:** 9
Anno di corso: I	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Elements of standard thermodynamics. Balance equation for mass, momentum, and energy. Linear constitutive equations for momentum, energy and mass transport. Newtonian fluid and viscosity. Fourier fluid and thermal conductivity. Fick equation for diffusive mass flux. Non-dimensionalization of balance equation and the introduction of non-dimensional groups (e.g., Reynolds number, Peclet number, etc…). Introduction to turbulence and simple description of turbulent transport phenomena through non-dimensional numbers. Solving of paradigmatic problems relative to the above contents.	
Obiettivi formativi: The aim of the course is to introduce the main concepts of thermodynamics, and the concept of balance equation for momentum, energy and mass and their mathematical formulation in terms of continuum thermo-mechanics. Solving of basic problems for the description of transport phenomena will also be tackled.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

Insegnamento: WAVES	
SSD: ING-IND/06	**CFU:** 6
Anno di corso: II	**Tipologia di Attività Formativa:** B
Contenuti estratti dalla declaratoria del SSD coerenti con gli obiettivi formativi del corso: Hyperbolic and dispersive waves; waves and first order equations; Burgers' equation; gasdynamics waves; the wave equation: acoustics, elasticity, electromagnetic waves; linear dispersive waves; group velocity; water waves; instability; brief overview of solitary waves.	
Obiettivi formativi: The behaviour of water waves and the propagation characteristics of sound and light are familiar from everyday experience. This course accounts for the physical description and the underlying mathematical theory of various wave phenomenologies, with emphasis on unifying ideas.	
Propedeuticità in ingresso: **Propedeuticità in uscita:**	
Tipologia degli esami e delle altre prove di verifica del profitto: Oral examination.	

ALLEGATO 2

REGOLAMENTO DIDATTICO DEL CORSO DI STUDI MATHEMATICAL ENGINEERING

CLASSE LM-44

Scuola: SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

Dipartimento: DIPARTIMENTO DI MATEMATICA E APPLICAZIONI R. CACCIOPPOLI

Regolamento in vigore a partire dall'a.a. 23-24

<table>
<tr><td colspan="3">Attività formativa: Further activities (ex art. 10, comma 5, lettera d)</td></tr>
<tr><td colspan="2">Attività: Linguistic knowledge, Soft skills, Training activities, Orientation activities</td><td>CFU: 3</td></tr>
<tr><td>Anno di corso: II</td><td colspan="2">Tipologia di Attività Formativa: F</td></tr>
<tr><td colspan="3">Contenuti della Attività coerenti con gli obiettivi formativi del corso:
- Language courses: linguistic knowledge
- Soft skill: technical competences useful to increasing the relevance of learning and qualifications in the labour market
- Training and internships orientation: activities aimed at facilitating professional choices</td></tr>
<tr><td colspan="3">Obiettivi formativi:
These activities are intended to contribute to the achievement of the training objectives of the Mathematical Engineeering Master Program.</td></tr>
<tr><td colspan="3">Propedeuticità in ingresso:
Propedeuticità in uscita:</td></tr>
<tr><td colspan="3">Tipologia delle prove di verifica del profitto: pass/fail evaluation</td></tr>
</table>

ALLEGATO 3

REGOLAMENTO DIDATTICO DEL CORSO DI STUDI
MATHEMATICAL ENGINEERING

CLASSE LM-44

Scuola: SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

Dipartimento: DIPARTIMENTO DI MATEMATICA E APPLICAZIONI R. CACCIOPPOLI

Regolamento in vigore a partire dall'a.a. 23-24

DOUBLE MASTER'S DEGREE PROGRAMME
in
MATHEMATICAL ANALYSIS AND MODELLING
between
University of Augsburg, University of Naples Federico II, University of Rouen, University of Sevilla, Tomsk State University.

This Double Degree regards the following diplomas:

- - the Master's Degree of the University of Augsburg "Mathematical Analysis and Modelling",
- - the Master's Degree of the University of Napoli Federico II "Mathematical Engineering",
- - the Master's Degree of the University of Napoli Federico II "Mathematics",
- - the Master's Diploma of the University of Rouen "Mathématiques et applications", parcours "Mathematical Analysis and Modelling" (MAM),
- - the Master's Diploma of the University of Sevilla "Máster Universitario en Matemáticas" (Universitary Master in Mathematics),
- - the Master's Diploma of the Tomsk State University "Mathematics", program "Mathematical Analysis and Modelling" (MAM).

The Agreement concerns the students of one of the partner universities enrolled in one the Master's programs listed above, who will follow the corresponding Master's program at one of the other universities.

The students, who will pass the examinations, will be awarded two Master's diplomas, one at the home university and the other at the host university.

Course of study

During the first year of the Master's program, students will study at their home university.

Students will carry on their studies according to the following schedule: the third or the third and fourth semesters will be studied at the host university.

The learning program at the host university during the mobility must be approved by the Steering Committee members of both home and host universities, and take into account the wishes of the student.

The language of instruction will be English as soon as necessary. It may be the local language if it is commonly understood by all students.

The partner universities undertake to inform and support the first-year Master, Bachelor and Engineering students about the conditions of the Double Degree Agreement in an appropriate way.

Examination and assessment

Students must comply with the training and examination procedures existing at the home and host university.

The following rules apply:

- A student should have obtained a minimum of 45 ECTS at the home university to be accepted at the host university.

- In order to obtain a double diploma, a student must obtain 120 ECTS, with a minimum of 60 ECTS obtained at the home university, and a minimum of 15 ECTS obtained at the host university (in addition to 30 ECTS of the master thesis).

Master's thesis

For the Master's thesis within the Double Master's Degree Programme, each student has two supervisors, one from the home university and the other one from the host university. The Master's thesis is written and is defended in English.

The Master's thesis defence takes place at the home or host university, after positive reports of two referees, one from the home and the other from the host university. The thesis defence is held according to the rules of the partner university where it takes place. The supervisor and, if requested, other members of the other university are invited to attend the defence, possibly by videoconference.

ALLEGATO 4

REGOLAMENTO DIDATTICO DEL CORSO DI STUDI MATHEMATICAL ENGINEERING

CLASSE LM-44

Scuola: SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

Dipartimento: DIPARTIMENTO DI MATEMATICA E APPLICAZIONI R. CACCIOPPOLI

Regolamento in vigore a partire dall'a.a. 23-24

Double Degree Program

This Double Degree regards the following diplomas:

- - the Master's Degree of the University of Augsburg "Mathematical Analysis and Modelling",
- - the Master's Degree of the University of Napoli Federico II "Mathematical Engineering",
- - the Master's Degree of the University of Napoli Federico II "Mathematics",
- - the Master's Diploma of the University of Rouen "Mathématiques et applications", parcours "Mathematical Analysis and Modelling" (MAM),
- - the Master's Diploma of the University of Sevilla "Máster Universitario en Matemáticas" (Universitary Master in Mathematics),
- - the Master's Diploma of the Tomsk State University "Mathematics", program "Mathematical Analysis and Modelling" (MAM).

During the first year of the Master's program, students will study at their home university. Students will carry on their studies according to the following schedule: the third or the third and fourth semesters will be studied at the host university. The learning program at the host university during the mobility must be approved by the Steering Committee members of both home and host universities, and take into account the wishes of the student. Credits will be recognized identifying groups of exams that give the same skills, which does not necessarily involve the same knowledge.

University of Rouen Normandy, France

Content:

Semestre 1 (30 crédits)
UE 1 : Analyse fonctionnelle (7 crédits)
UE 2 : Probabilités (5 crédits)
UE 3 : Analyse des EDP (5 crédits)
UE 4 : Compléments d'analyse (5 crédits)
UE 5 : Anglais (2 crédits)
UE 6 : Préprofessionnalisation (1 crédit)
UE 7 : Analyse Numérique des EDP (5 crédits)
Semestre 2 (30 crédits)
UE 1 : Initiation à la recherche mathématique (4 crédits)
UE 2 : Modélisation par les ODE-Contrôle (7 crédits)
UE 3 : Modélisation par des EDP en Sciences (7 crédits)
UE 4 : Anglais – Obligatoire (2 crédits)
UE 5 : Calcul scientifique (5 crédits)
Modélisation par les probabilités (5 crédits)
Semestre 3 (30 crédits)
UE 1 : Cours communs
Outils informatiques, Documentation (3 crédits)
Cours de langue (3 crédits)
UE 2 : Cours de base Statistique asymptotique (6 crédits)
UE 3 : Options au choix (18 crédits)
3 options de 6 crédits à choisir parmi
Analyse des EDP A
Calcul scientifique A
Contrôle et optimisation A
Contrôle et optimisation B
Statistiques A
Semestre 4 (30 crédits)
UE 1 : Cours de langue (3 crédits)
UE 2 : Cours thématique (6 crédits)
Le cours thématique sera choisi par l'étudiant parmi les options offertes au niveau master dans le but de compléter sa formation et d'approfondir la thématique de son mémoire ou stage.
UE 3 : Mémoire recherche ou Stage en entreprise (21 crédits)

The University of Naples, Italy

Content:

I YEAR				
TEACHING	**ECTS**	**Courses**	**ECTS/ Course**	**Typology**
Institutions of Higher Analysis	12	1	12	Characterizing - advanced theoretical training
Institutions of Higher Mathematical Physics	9	1	9	Characterizing - modeling application training
Scientific Calculus	9	1	9	Characterizing - modeling application training
Optional in the table B1/1	12	2	6	Characterizing - advanced theoretical training
Optional in the table B1/2	18	3	6	Characterizing - modeling application training
TOTAL I YEAR	**60**			

II YEAR				
TEACHING	**ECTS**	**Courses**	**ECTS/ course**	**Typology**
2 courses optional in the table B1/3	12	2	6	Affine or integrative
Optional in the tables B1/1, B1/2 and B1/3	12			Optional
Language and computer science	4			Other activities
Thesis	32			Thesis
TOTAL II YEAR	**60**			

TABLE B1/1

(Teachings characterizing advanced theoretical training)

TEACHINGS	**ECTS**	**Courses**	**ECTS/course**	**Typology**
Real Analysis	6	1	6	Characterizing
Calcolus of Variations	6	1	6	Characterizing
Functional Analysis	6	1	6	Characterizing
Partial differential equations	6	1	6	Characterizing

TABLE B1/2

(Insegnamenti caratterizzanti formazione applicativa modellistica)

TEACHING	**ECTS**	**Courses**	**ECTS/course**	**Typology**
Stocastical processes	6	1	6	Characterizing
Stochastical models and statistical methods	6	1	6	Characterizing
Fluid Dynamics	6	1	6	Characterizing
Higher Mechanics	6	1	6	Characterizing
Continuum Mechanics	6	1	6	Characterizing
Evolutionary processes in Mathematical Physics	6	1	6	Characterizing

Numerical methods for Ordinary Differential Equations	6	1	6	Characterizing
Numerical methods for the data analysis	6	1	6	Characterizing
Numerical methods for the datamining	6	1	6	Characterizing
Risoluzione Numerica di Equazioni alle Derivate Parziali	6	1	6	Characterizing
Combinatorial Ottimizzation	6	1	6	Characterizing
Operational Research	6	1	6	Characterizing

TABLE B1/3

(Affine or supplemental training)

TEACHINGS	**ECTS**	**Courses**	**ECTS/ course**	**Typology**
Modern Physics	6	1	6	Affine
Complements of Physics	6	1	6	Affine
Preparing Educational Experiences	6	1	6	Affine
Physics Didactics	8	1	8	Affine
Programming Laboratory 2	6	1	6	Affine
Parallel and Distributed Calculation	6	1	6	Affine
Elements of Mathematical Economics	6	1	6	Affine

Insegnamento o attività formativa	**CFU**	**SSD**	**Tip.**	**Ambiti Disciplinari**
Real and Functional Analysis	9	MAT/05	B	Mat., Fis., Inf.
Mathematical Physical Models	*9*	MAT/07	B	Mat., Fis., Inf.
Numerical Methods	9	MAT/08	B	Mat., Fis., Inf.
Thermodynamics and Transport Phenomena	9	ING-IND/22	B	Ingegneristico
Nonlinear Systems	6	ING-INF/04	B	Ingegneristico
A scelta nel Gruppo I	6		B	
A scelta nel Gruppo III	6		C	
Computational Fluid Dynamics	9	ING-IND/06	B	Ingegneristico
Electrodynamics	9	ING-IND/31	B	Ingegneristico
A scelta nel Gruppo II	6		B	Ingegneristico
A scelta nel Gruppo III	6		C	
A scelta autonoma dello studente	12		D	
Ulteriori conoscenze	3		F	
Prova finale	21		E	

CURRICULUM A

Gruppo	**Insegnamento o attività formativa**	**CFU**	**SSD**	**Tip.**
I	Geometric Structures and Topology	6	MAT/03	B
	Mathematical Methods for Engineering*	6	MAT/05	B

	Calculus of Variations*	6	MAT/05	B
	Discrete Mathematics	6	MAT/02	B
	Stochastic Processes	6	MAT/06	B
	Operational Research	6	MAT/09	B
	Algebraic Structures and Advanced Linear Algebra*	6	MAT/02	B
	Mathematics for Cryptography	6	INF/01	B
	Computational Complexity	6	INF/01	B
II	Optoelectronics	6	ING-INF/01	B
	Electromagnetic Fields	6	ING-INF/02	B
	Algorithms and Parallel Computing	6	ING-INF/05	B
	Information Theory	6	ING-INF/05	B
	Systems Identification	6	ING-INF/04	B
III	Signals Theory*	6	ING-INF/03	C
	Economic Theory*	6	SECS-S/06	C
	Statistical Quality Control	6	SECS-S/02	C
	Modern Physics*	6	FIS/01	C
	Solid State Physics	6	FIS/03	C

CURRICULUM B

Gruppo	Insegnamento o attività formativa	CFU	SSD	Tip. (*)
I	Geometric Structures andTopology	6	MAT/03	B
	Mathematical Methods for Engineering*	6	MAT/05	B
	Partial Differential Equations *	6	MAT/05	B
	Advanced Applied Engineering Mathematics*	6	MAT/07	B
	Differential Geometry	6	MAT/03	B
	Operational Research	6	MAT/09	B
II	Mechanical Vibrations	6	ING- IND/13	B
	Waves	6	ING- IND/06	B
	Heat Transfer	6	ING- IND/10	B
	Electromagnetic Fields	6	ING- INF/02	B
	Analysis and Control of Complex Systems	6	ING- INF/04	B
	Nonlinear Dynamics and Control		ING- INF/04	B
	Hydraulics		ICAR/01	B
	Theory of Elasticity		ICAR/08	B
III	Chemical Process Analysis and Simulation*	6	ING- IND/26	C
	Economic Theory*	6	SECS- S/06	C
	Statistical Quality Control	6	SECS- S/02	C
	Modern Physics*	6	FIS/01	C
	Solid State Physics	6	FIS/03	C

Tomsk State University, Russia

Content:

№	Title blocks, modules, courses, practices, research	The distribution of disciplines per semesters				
		Total Credits (ECTS)	1	2	3	4
Block 1. Disciplines		**59**				
Basic courses (General Science)		**21**				
B.1.1	Philosophy and methodology of scientific knowledge	3				3
B.1.2	History and methodology of mathematics	3		3		
B.1.3	Modern computer technologies	5	3	2		
B.1.4	Mathematical models	5		5		
B.1.5	Foreign language (English) Foreign language (Russian) Foreign language (French)	5			2	3
Options (Professional Courses)		**25**				
O.1.1	Additional chapters of mathematical analysis	5	5			
O.1.2	Stochastic Modelling	6	6			
O.1.3	Numerical methods	6		6		
O.1.4	Optimization methods	5		5		
O.1.5	Option 1	3			3	
Options (Elective Courses)		**13**				
O.1.6	Option 2	4	4			
O.1.7	Option 3	3			3	
O.1.8	Option 4	3			3	
O.1.9	Option 5	3				3
Block 2. Research and internship		**55**				
B.2.1	Research	49	12	9	19	9
B.2.2	Internship	6				6
Block 3. Thesis with defense		**6**				
B.3.1	Thesis with defense	6				6
Total		**120**	30	30	30	30

List of options

Option 1 (S3)	Industrial mathematics
	Modern methods of data mining
Option 2 (S1)	Functional analysis and its applications
	Qualitative analysis of ODE
Option 3 (S3)	Statistical analysis and forecasting of time series
	Multivariate statistical methods
Option 4 (S3)	Methods of spline functions
	Methods of solving ill-posed problems
Option 5 (S4)	Methods of parallel computing
	Organization and Software High

University of Seville, Spain

Content:

PRIMER CUATRIMESTRE		
Asignatura	**Crédito ECTS**	**Carácter**
Algorítmica	3	Optativo
Análisis Funcional	6	Optativo
Análisis Real y Armónico	6	Optativo
Ecuaciones en Derivadas Parciales y Aplicaciones	6	Optativo
Geometría Algebraica	6	Optativo
Geometría SemiRiemanniana	6	Optativo
Lógica Computacional y Teoría de Modelos	6	Optativo
Minería Estadística de datos	6	Optativo
Modelado y Predicción estadística	6	Optativo
Optimización	6	Optativo
Procesos Estocásticos. Aplicaciones	6	Optativo
Sistemas Dinámicos	6	Optativo
Teoría de Grafos y Geometría Computacional	6	Optativo
Teoría de la Complejidad Computacional	3	Optativo
Topología Algebraica	6	Optativo
SEGUNDO CUATRIMESTRE		
Asignatura	**Créditos**	**Carácter**
Álgebras no Asociativas y Teoría de Representaciones	6	Optativo
Análisis Numérico de Ecuaciones Diferenciales	6	Optativo
Criptografía	6	Optativo
Fractales y Proceso Iterativos	3	Optativo
Modelos Matemáticos en Logística y Transporte	6	Optativo
Modelado y Simulación Numérica	3	Optativo
Modelado y Simulación Topológica	3	Optativo
Teoría de Juegos	3	Optativo
Variable Compleja y Operadores	6	Optativo
Trabajo Fin de Máster (Módulo III)	9	Obligatorio

PRIMER/SEGUNDO CUATRIMESTRE (MÓDULO II)	
Introducción al Trabajo Fin de Máster	9
Prácticas Externas Optativas	9

University of Augsburg, Germany

Content:

Semester 1
Preparatory module: Supplements on Analysis (6 credits)
Preparatory module: Functional Analysis/Partial Differential Equations (6 credits)
Calculus of Variations (9 credits)
Stochastic Differential Equations(9 credits)
Semester 2
Preparatory module: Supplements on Numerics (6 credits)
Nonlinear Partial Differential Equations (9 credits)
Softskill module (9 credits)
Seminar on Analysis (6 credits)
Semester 3
Software project (6 credits)
Control theory (9 credits)
Mathematical Modelling (9 credits)
Advanced Seminar on Analysis (6 credits)
Semester 4
Master thesis incl. presentation (30 credits)

GRADING CONVERSION CHART

	FAIL	PASS	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT
FRANCE	0-9,99	10-11,99	12-13,99	14-15,99	16-17,99	18-20
GERMANY	4,01-5	3,51-4	2,51-3,50	1,51-2,50	1,50-1	
ITALY (regular courses)	0-17	18-21	22-25	26-27	28-29	30
ITALY (Master's thesis)	0	1-2	3-4	5-6	7-8	9
RUSSIA	Failed	Satisfactory		Good		Excellent
SPAIN	0-4,9	5-6,9		7-8,9	9-10	