

UNIVERSITA' DEGLI STUDI DI NAPOLI "FEDERICO II"
DIPARTIMENTO DI MATEMATICA E APPLICAZIONI
"R. CACCIOPPOLI"

REGOLAMENTO DIDATTICO DEL
CORSO DI LAUREA MAGISTRALE IN MATHEMATICAL
ENGINEERING

(Redatto sulla base del D.M. 270/04 e valido a partire dall'A. A 2021/2022)

ARTICOLO 1

Definizioni

- 1) Ai sensi del presente Regolamento si intende:
 - a) per "Dipartimento" il Dipartimento di Matematica e Applicazioni "R.Caccioppoli" dell'Università degli Studi di Napoli Federico II
 - b) per "D.M. 590/99", il Decreto Ministeriale n. 590 riguardante "Norme concernenti l'autonomia didattica degli atenei", approvato con decreto del Ministro dell'università e della ricerca scientifica e tecnologica il 3 novembre 1999
 - c) per "D.M. 270/04", il Decreto Ministeriale n. 270 riguardante "Modifiche al regolamento recante norme concernenti l'autonomia didattica degli atenei", approvato con decreto del Ministro dell'università e della ricerca scientifica e tecnologica il 22 ottobre 2004
 - d) per "Regolamento Didattico di Ateneo", il regolamento approvato dall'Università degli Studi di Napoli Federico II ai sensi dell'art. 11 del D.M. 270/04
 - e) per "Corso di Laurea Magistrale", il Corso di Laurea Magistrale in Mathematical Engineering, come individuato dal successivo art. 2
 - f) per "Ordinamento Didattico" l'Ordinamento Didattico del Corso di Laurea Magistrale in Mathematical Engineering allegato al Regolamento Didattico d'Ateneo,
 - g) per CFU il Credito Formativo Universitario così come definito nel D.M. 270/04
 - h) per SSD il Settore Scientifico Disciplinare

ARTICOLO 2

Titolo e Corso di Laurea

- 1) Il presente Regolamento Didattico disciplina il Corso di Laurea Magistrale in Mathematical Engineering afferente al Dipartimento di Matematica Applicazioni "R.Caccioppoli" dell'Università degli Studi di Napoli Federico II, appartenente alla classe LM-44, "Modellistica Matematico-Fisica per l'Ingegneria" di cui alla tabella allegata al D.M. 16 marzo 2007, ed al relativo Ordinamento Didattico inserito nel Regolamento Didattico di Ateneo
- 2) Gli obiettivi formativi del Corso di Laurea Magistrale sono quelli fissati nell'Ordinamento Didattico allegato al Regolamento Didattico di Ateneo
- 3) I risultati di apprendimento del Corso di Laurea Magistrale attesi, espressi secondo gli indicatori di Dublino, sono quelli fissati nell'Ordinamento Didattico allegato al Regolamento Didattico di Ateneo.
- 4) Gli sbocchi occupazionali e professionali previsti per il Corso di Laurea Magistrale sono quelli descritti nell'Ordinamento Didattico allegato al Regolamento Didattico di Ateneo

ARTICOLO 3

Struttura didattica

- 1) Sono organi del Corso di Laurea Magistrale
 - a. La Commissione di Coordinamento Didattico dei Corsi di Studi in Mathematical Engineering
 - b. il Presidente della Commissione di Coordinamento Didattico dei Corsi di Studi in Mathematical Engineering
 - c. la Giunta ove il consiglio ne deliberi l'attivazione
- 2) Il Corso di Laurea Magistrale è retto, congiuntamente alla Commissione di Coordinamento Didattico dei Corsi di Studi in Mathematical Engineering, costituita secondo quanto previsto dallo Statuto, dal Regolamento Didattico di Ateneo.
- 3) La Commissione di Coordinamento Didattico dei Corsi di Studi in Mathematical Engineering è presieduta da un Presidente, eletto secondo quanto previsto dallo Statuto. Il Presidente ha la responsabilità del funzionamento del Consiglio, ne convoca le riunioni ordinarie e straordinarie.
- 4) La Commissione di Coordinamento Didattico dei Corsi di Studi in Mathematical Engineering e il Presidente svolgono i compiti previsti dal Regolamento Didattico di Ateneo.

ARTICOLO 4

Requisiti di ammissione al Corso di Laurea Magistrale, attività formative propedeutiche e integrative

- 1) I requisiti di ammissione sono quelli indicati nei successivi commi 2, 3, 4 e 5 del presente articolo, integrati con i requisiti riportati nell'Allegato A al presente regolamento.
- 2) Almeno una volta l'anno la Commissione di Coordinamento Didattico del Corso di Laurea magistrale in Mathematical Engineering si riunisce per deliberare sulle ammissioni al Corso di Laurea Magistrale
- 3) Per essere ammessi al corso di Laurea Magistrale occorre essere in possesso di un titolo di Laurea nelle Classi delle Lauree L-7 Ingegneria civile e ambientale, L-8 Ingegneria dell'informazione, L-9 Ingegneria Industriale, L-23 Scienze e tecniche dell'edilizia, L-35 Scienze matematiche, ovvero titoli equipollenti. Sarà inoltre richiesta la conoscenza della lingua inglese corrispondente al livello non inferiore a B2. (vedi allegato A)
- 4) Studenti in possesso di lauree non appartenenti alle classi indicate al precedente comma 3), di cui alla tabella allegata al D.M. 207/04, possono essere ammessi al Corso di Laurea Magistrale su parere positivo della Commissione di Coordinamento Didattico del Corso di Laurea magistrale.
- 5) La Commissione di Coordinamento Didattico del corso di laurea magistrale in Mathematical Engineering potrà proporre anno per anno altre modalità dell'eventuale prova di ammissione tendente ad accertare i requisiti di cui al precedente comma 1. Tale modalità verrà inserita nel manifesto degli studi e dovrà comunque prevedere l'analisi individuale della personale preparazione.
- 6) Al momento dell'iscrizione, gli studenti sono obbligati a scegliere un curriculum tra quelli proposti nell'allegato B1.

ARTICOLO 5

Svolgimento della didattica, tipologia e articolazione degli insegnamenti

- 1) La durata del Corso di Laurea Magistrale e' di 2 anni, corrispondenti a 120 CFU
- 2) Gli Allegati B1 e B2 costituiscono parte integrante del presente Regolamento.
- 3) L'Allegato B1 definisce l'articolazione del Corso di Laurea Magistrale in Mathematical Engineering, con l'elenco degli insegnamenti, la loro collocazione negli anni del corso, la sequenza temporale, l'eventuale articolazione in moduli e i crediti ad essi assegnati, e delle altre attività formative, con l'indicazione dei SSD degli ambiti di riferimento.
- 4) Secondo quanto previsto dal D.M. 270/04, le attività formative riportate nell'Allegato B1 sono distinte in
 - a) Attività caratterizzanti, finalizzate all'acquisizione delle competenze specifiche nel campo della Matematica
 - b) Attività affini o integrative, finalizzate all'acquisizione di competenze integrative a quelle di base e caratterizzanti
 - c) Attività a scelta degli studenti, finalizzata a permettere il completamento e la personalizzazione del percorso di studi da parte degli studenti
 - d) Attività finalizzate alla preparazione della prova finale per il conseguimento del titolo di studio ,
 - e) Attività finalizzate all'acquisizione di ulteriori conoscenze informatiche, linguistiche o relazionali.
- 5) La ripartizione dei CFU nelle varie attività formative è quella definita nell'Ordinamento Didattico.
- 6) L'Allegato B1 al presente Regolamento è redatto nel rispetto di quanto previsto dal Regolamento Didattico di Ateneo. In particolare, esso può prevedere l'articolazione dell'offerta didattica in moduli di diversa durata, con attribuzione di diverso peso nell'assegnazione dei crediti formativi universitari corrispondenti.
- 7) Oltre ai corsi di insegnamenti ufficiali, di varia durata, che terminano con il superamento dei relativi esami, l'Allegato B1 al presente Regolamento può prevedere l'attivazione di corsi di sostegno, seminari, esercitazioni in laboratorio o in biblioteca, esercitazioni di pratica testuale, esercitazioni di pratica informatica e altre tipologie di insegnamento ritenute adeguate al conseguimento degli obiettivi formativi del Corso di Laurea Magistrale
- 8) Le schede che costituiscono l'allegato B2 definiscono per ciascun insegnamento e attività formativa:
 - a) gli obiettivi formativi specifici e i relativi contenuti con l'indicazione del SSD di riferimento
 - b) i crediti attribuiti e l'eventuale suddivisione in moduli
 - c) le eventuali propedeuticità;
 - d) la modalità di accertamento del profitto che consenta il conseguimento dei relativi crediti.
- 9) Nel caso di corsi d'insegnamento articolati in moduli, questi potranno essere affidati alla collaborazione di più Professori di ruolo e/o Ricercatori.

ARTICOLO 6

Manifesto degli studi e piani di studio

- 1) La Commissione di Coordinamento Didattico del corso di laurea magistrale propone annualmente:
 - a) le alternative offerte e consigliate, per l'eventuale presentazione da parte dello studente di un proprio piano di studio;
 - b) le modalità di svolgimento di tutte le attività didattiche;
 - c) l'articolazione delle attività didattiche in semestri;
 - d) la data di inizio e di fine delle singole attività didattiche (lezioni frontali, moduli didattici, seminari etc.);
 - e) i criteri di assegnazione degli studenti a ciascuno degli eventuali corsi plurimi;

- f) le disposizioni sugli eventuali obblighi di frequenza;
- g) le scadenze connesse alle procedure per le prove finali;
- h) le modalità di copertura degli insegnamenti e di tutte le altre attività didattiche

2) La richiesta di approvazione di piani di studi individuali, presentati alla Segreteria studenti entro i tempi fissati dal Senato Accademico, saranno vagliati, sulla base della congruità con gli obiettivi formativi specificati nell'Ordinamento Didattico, da un'apposita Commissione deliberante nominata dal Consiglio di Coordinamento dei Corsi di Studi in Matematica e approvati, respinti o modificati entro il termine fissato dal Regolamento Didattico di Ateneo.

ARTICOLO 7

Orientamento e tutorato

1) Le attività di orientamento e tutorato sono organizzate e regolamentate dalla Commissione di coordinamento didattico del corso di studi, secondo quanto stabilito dal Regolamento Didattico di Ateneo.

ARTICOLO 8

Ulteriori iniziative didattiche dell'Università

1) In conformità al Regolamento Didattico di Ateneo, dalla Commissione di coordinamento didattico del corso di studi Mathematical Engineering può proporre all'Università di organizzare iniziative didattiche di perfezionamento, corsi di preparazione agli Esami di Stato per l'abilitazione all'esercizio delle professioni e dei concorsi pubblici e per la formazione permanente, corsi per l'aggiornamento e la formazione degli insegnanti di Scuola Superiore. Tali iniziative possono essere promosse attraverso convenzioni con Enti pubblici o privati che intendano commissionarle.

ARTICOLO 9

Trasferimenti, passaggi di Corso, ammissione a prove singole

1) I trasferimenti, i passaggi e l'ammissione a prove singole sono regolamentati dal Regolamento Didattico di Ateneo.

2) dalla Commissione di coordinamento didattico del corso di studi Mathematical Engineering potrà, anno per anno, deliberare che in casi specifici l'accettazione di una pratica di trasferimento sia subordinata ad una prova di ammissione predeterminata.

ARTICOLO 10

Esami di profitto

1) Le norme relative agli esami di profitto sono quelle contenute nel regolamento Didattico di Ateneo .

2) Nel caso di corsi plurimi i relativi esami vanno tenuti con le medesime modalità.

3) Eventuali crediti relativi alla conoscenza di una lingua dell'Unione Europea diversa dall'italiano e dall'inglese sono acquisiti attraverso una prova specifica di lettura e traduzione all'impronta di un testo scientifico in lingua, ovvero attraverso certificazioni rilasciate da strutture competenti, riconosciute dall'Università.

4) Il Presidente della Commissione di coordinamento didattico del corso di studi Mathematical Engineering definisce all'inizio dell'anno accademico le date degli esami curando che:

- a) esse siano rese tempestivamente pubbliche nelle forme previste;
- b) non vi siano sovrapposizioni di esami, relativi ad insegnamenti inseriti nel medesimo anno di corso dello stesso *curriculum*;
- c) sia previsto, ove necessario, un adeguato periodo di prenotazione;
- d) eventuali modifiche del calendario siano rese pubbliche tempestivamente e, in ogni caso, non prevedano anticipazioni.

ARTICOLO 11

Studenti a contratto

1) Il Consiglio di Coordinamento dei Corsi di Studi determina, anno per anno, forme di contratto offerte agli studenti che chiedano di seguire gli studi in tempi più lunghi di quelli legali. A tali studenti si applicano le norme previste dal Regolamento Didattico di Ateneo.

ARTICOLO 12

Doveri didattici dei Professori di ruolo e dei Ricercatori

1) I doveri didattici dei Professori di ruolo e dei Ricercatori sono quelli previsti dal Regolamento Didattico di Ateneo.

ARTICOLO 13

Prova finale e conseguimento del titolo di studio

1) La Laurea Magistrale in Mathematical Engineering si consegue al termine del Corso di Laurea a seguito di prova finale e comporta l'acquisizione di 120 CFU.

2) L'Allegato C al presente Regolamento disciplina:

- a) le modalità della prova finale, comprensiva in ogni caso di un'esposizione dinanzi a una apposita commissione;
- b) le modalità della valutazione conclusiva, che deve tenere conto dell'intera carriera dello studente all'interno del Corso di Laurea, dei tempi e delle modalità di acquisizione dei crediti formativi universitari, della prova finale.

3) Per accedere alla prova finale lo studente deve avere acquisito il quantitativo di crediti universitari previsto dall'Allegato B1 al presente Regolamento, meno quelli previsti per la prova stessa.

ALLEGATO A **(Requisiti d'ingresso e attività formative propedeutiche e integrative)**

Per accedere al Corso di Laurea Magistrale in Mathematical Engineering occorre possedere i requisiti di cui al precedente articolo 4.

a) In mancanza del requisito di conoscenza della lingua inglese, corrispondente ad un livello di conoscenza non inferiore a B2, lo studente potrà accedere al corso di laurea magistrale in Mathematical Engineering. La certificazione attestante il livello B2 di conoscenza della lingua inglese dovrà essere acquisita entro il I anno del corso di studi e in mancanza di tale certificazione, lo studente non è ammesso a sostenere gli esami del secondo anno.

b) Per studenti non appartenenti alle classi previste dall' art. 4 comma 3, la Commissione di Coordinamento Didattico del corso di laurea magistrale in Mathematical Engineering può comunque deliberare la non ammissione al corso di Laurea Magistrale con parere motivato. L'ammissione ai corsi di laurea magistrale della classe richiede il possesso di requisiti curriculari che prevedano, comunque, un'adeguata padronanza di metodi e contenuti scientifici generali nelle discipline scientifiche di base e nelle discipline dell'ingegneria, propedeutiche a quelle caratterizzanti previste nell'ordinamento della presente classe di laurea magistrale.

ALLEGATO C **(Prova Finale)**

La prova finale consiste nella discussione di una tesi elaborata dallo studente che riporti risultati originali riferiti a temi avanzati di interesse ingegneristico. L'elaborato dovrà rispondere al requisito di bilanciare opportunamente l'analisi del problema ingegneristico e lo sviluppo degli strumenti della modellistica matematica funzionali alla sua risoluzione. La tesi sarà predisposta dal candidato sotto la guida di uno o più relatori anche esterni al corso di laurea magistrale. La preparazione della tesi potrà anche essere svolta presso aziende pubbliche o private, nonché presso centri di ricerca o laboratori universitari per un periodo di tempo congruente con i crediti assegnati.

La prova per il conseguimento del titolo finale consiste in una discussione pubblica dell'elaborato di tesi, presentato anche in forma scritta, dinanzi ad una commissione di esame, secondo le modalità disciplinate dal Regolamento Didattico di Ateneo. La discussione mira ad accertare le capacità di sintesi e la maturità culturale raggiunta dallo studente a conclusione del curriculum di studi, nell'ambito delle competenze previste negli obiettivi formativi del corso di studio. In particolare lo studente dovrà dimostrare la padronanza degli argomenti trattati, la capacità di operare in modo autonomo ed un buon livello di capacità di comunicazione.

Insegnamento o attività formativa	Modulo	CFU	SSD	Ti p. (*)	Ambiti Disciplinari	Propedeuticità
I Anno						
Real and Functional Analysis		9	MAT/05	2	Mat., Fis., Inf.	
Mathematical Physical Models		9	MAT/07	2	Mat., Fis., Inf.	
Numerical Methods		9	MAT/08	2	Mat., Fis., Inf.	
Thermodynamics and Transport Phenomena		9	ING-IND/22	2	Ingegneristico	
Nonlinear Systems		6	ING-INF/04	2	Ingegneristico	
A scelta nel Gruppo I		6		2		
A scelta nel Gruppo III		6		3		
II Anno						
Computational Fluid Dynamics		9	ING-IND/06	2	Ingegneristico	
Electrodynamics of continuous media		9	ING-IND/31	2	Ingegneristico	
A scelta nel Gruppo II		6		2	Ingegneristico	
A scelta nel Gruppo III		6		3		
A scelta autonoma dello studente		12		4		
Ulteriori conoscenze		3		6		
Prova finale		21		5		

CURRICULUM A

Gruppo	Insegnamento o attività formativa	CFU	SSD	Tip. (*)	Ambiti Disciplinari	Propedeuticità
I	Geometric Structures and Topology	6	MAT/03	2	Mat. Fis. Inf.	
	Mathematical Methods for Engineering	6	MAT/05	2	Mat. Fis. Inf.	
	Calculus of Variations	6	MAT/05	2	Mat. Fis. Inf.	
	Discrete Mathematics	6	MAT/02	2	Mat. Fis. Inf.	
	Stochastic Processes	6	MAT/06	2	Mat. Fis. Inf.	
	Operational Research	6	MAT/09	2	Mat. Fis. Inf.	
	Algebraic Structures and Advanced Linear Algebra	6	MAT/02	2	Mat. Fis. Inf.	
	Mathematics for Cryptography	6	INF/01	2	Mat. Fis. Inf.	
	Algorithms and Parallel Computing	6	INF/01	2	Mat. Fis. Inf.	
	Computational Complexity	6	INF/01	2	Mat. Fis. Inf.	

II	Optoelectronics	6	ING-INF/01	2	Ingegneristico	
	Electromagnetic Fields	6	ING-INF/02	2	Ingegneristico	
	Information Theory	6	ING-INF/05	2	Ingegneristico	
	Systems Identification	6	ING-INF/04	2	Ingegneristico	
III	Signals Theory	6	ING-INF/03	3		
	Economic Theory	6	SECS-S/06	3		
	Statistical Methods for Industrial Process Monitoring	6	SECS-S/02	3		
	Modern Physics	6	FIS/01	3		
	Solid State Physics	6	FIS/03	3		

CURRICULUM B

Gruppo	Insegnamento o attività formativa	CFU	SSD	Tip. (*)	Ambiti Disciplinari	Propedeuticità
I	Geometric Structures and Topology	6	MAT/03	2	Mat. Fis. Inf.	
	Mathematical Methods for Engineering	6	MAT/05	2	Mat. Fis. Inf.	
	Partial Differential Equations	6	MAT/05	2	Mat. Fis. Inf.	
	Advanced Applied Engineering Mathematics	6	MAT/07	2	Mat. Fis. Inf.	
	Differential Geometry	6	MAT/03	2	Mat. Fis. Inf.	
	Operational Research	6	MAT/09	2	Mat. Fis. Inf.	
II	Mechanical Vibrations	6	ING-IND/13	2	Ingegneristico	
	Waves	6	ING-IND/06	2	Ingegneristico	
	Heat Transfer	6	ING-IND/10	2	Ingegneristico	
	Electromagnetic Fields	6	ING-INF/02	2	Ingegneristico	
	Analysis and Control of Complex Systems	6	ING-INF/04	2	Ingegneristico	
	Nonlinear Dynamics and Control		ING-INF/04	2	Ingegneristico	
	Environment Fluid Dynamics and Hydraulics		ICAR/01	2	Ingegneristico	
	Theory of Elasticity		ICAR/08	2	Ingegneristico	
III	Chemical Process Analysis and Simulation	6	ING-IND/26	3		
	Economic Theory	6	SECS-	3		

			S/06			
	Statistical Methods for Industrial Process Monitoring	6	SECS-S/02	3		
	Modern Physics	6	FIS/01	3		
	Solid State Physics	6	FIS/03	3		

(*) **Legenda delle tipologie delle attività formative ai sensi del DM 270/04**

Attività formativa	1	2	3	4	5	6	7
rif. DM270/04	Art. 10 comma 1, a)	Art. 10 comma 1, b)	Art. 10 comma 5, a)	Art. 10 comma 5, b)	Art. 10 comma 5, c)	Art. 10 comma 5, d)	Art. 10 comma 5, e)

Course Title: Advanced Applied Engineering Mathematics	Number of Units: 1
SSD : MAT/07	CFU: 9
Course aims: Introduction to mathematical modelling for Engineering. The course presents diffusion models, wave motion models, steady-state models, Euler-Bernoulli model for beams, Finite Difference Method and Finite Element Method for Partial Differential Equations.	
Course Description Heat conduction and diffusion. Parabolic Partial Differential Equations. Initial boundary value problems. Finite Difference Method. Consistency. Convergence, Stability. Von Neuman criterion. Finite Element Method. Weak form. Dirac delta function. Elliptic partial differential equations and steady-state processes. Wave motions and hyperbolic partial differential equations. Euler-Bernoulli equation and partial differential equations of higher order.	
Assumed Background: Calculus, Elementary Mechanics.	
Assessment methods: Oral examination	

Course Title: Algebraic Structures and Advanced Linear Algebra	Number of Units: 1
SSD: MAT03	CFU : 6
Course aims: To provide students with a good understanding of the concepts and methods of advanced linear algebra aimed at solving engineering problems.	
Course Description: Symmetric bilinear and hermitian forms. Diagonalization of symmetric bilinear forms and Gauss's theorem. 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.	
Assumed Background: Linear Algebra at undergraduate level	
Assessment methods: Oral examination.	

Course Title: Algorithms and Parallel Computing	Number of Units: 1
SSD : INF/01	CFU: 6
Course aims: 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.	
Course Description: 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.	
Assumed Background: Computer Programming – basic level; C language – basic level; Use of Linux – basic level; Matrix Computation Algorithms – basic level; Array sorting Algorithms – basic level	
Assessment methods: Lab tests during the course; final written/oral test.	

Course Title: Analysis and Control of Complex Systems	Number of Units: 1
SSD : ING-INF/04	CFU: 6
Course aims: 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.	
Course Description: 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.	
Assumed Background: Nonlinear Systems	
Assessment methods: Oral examination and project work	

Course Title: Calculus of Variations	Number of Units 1
SSD : MAT05	CFU: 6
Course aims: 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.	
Course Description: Introduction to Calculus of Variations in vectorial spaces. Function spaces. Weak and strong minimizers. Fréchet and Gâteaux differentiation. One-dimensional Euler-Lagrange equations. Second Euler-Lagrange and Erdmann-Weierstrass equations. Minimization with constraints. Geodesics on surfaces. Hamiltonian formulation. Hamilton-Jacobi equations. Optimal control problems and examples. Excess. Legendre condition. Applications: Isoperimetric problems, geodesics, problem of minimal area, equilibrium configurations of membranes, equilibrium and elasticity. Worked examples.	
Assumed Background: Mathematical Analysis at undergraduated level	
Assessment methods: Oral examination	

Course Title: Chemical Process Analysis and Simulation	Number of Units: 1
SSD : ING-IND/26	CFU: 6
Course aims: The course will focus on the mathematical description of chemical and physical phenomena that occur in the process industry equipments.	
Course Description: 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.	
Assumed Background:	
Assessment methods:	

Course Title: Computational Complexity	Number of Units: 1
SSD : INF/01	CFU: 6
Course aims: 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.	
Course Description: 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.

Assumed Background: Real and functional analysis, basic logic, basic algorithmics

Assessment methods: Written and oral examination

Course Title: Computational Fluid Dynamics	Number of Units: 1
SSD : ING-IND/06	CFU: 9
Course aims: 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	
Course Description Finite volume and finite difference discretization of model transport equations, conservative and non conservative formulations. Numerical integration of incompressible Navier-Stokes equations: vorticity-streamfunction and primitive variable formulations. Fractional step methods and the treatment of the pressure Poisson equation. Discretization techniques for nonlinear convective terms and associated conservation properties. Turbulent models and introduction to the numerical simulation of turbulent flows. Numerical integration of Euler equations for compressible flows and introduction to the study of shock capturing schemes.	
Assumed Background: Numerical methods	
Assessment methods: Written text on a case study and oral examination	

Course Title: Differential Geometry	Number of Units: 1
SSD : MAT03	CFU: 6
Course aims: To provide students with a good understanding of the concepts and methods of differential geometry aimed at solving engineering problems.	
Course Description: space. Tangent bundle and vector fields. Vector bundles. Differentials. Cotangent bundle and differential forms. Tensor algebra. Tensor bundles and tensor fields. Flux of a vector field. Lie derivative and Lie bracket. Integration on manifolds. Closed and exact forms. Stokes Theorem. Connections on a vector bundle. Covariant derivative. Riemannian structures and Levi-Civita connection. Geodetics.	
Assumed Background: Linear Algebra at undergraduate level	
Assessment methods: : Oral examination.	

Course Title: Discrete Mathematics	Number of Units 1
SSD : MAT02	CFU: 6
Course aims: 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.	
Course Description: The course will be accomplished through different topics. First of all the basic concepts and terminology 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.

Assumed Background: undergraduate level

Assessment methods: Oral examination

Course Title: Economic Theory	Number of Units: 1
SSD : SECS-S/06	CFU: 6
Course aims: 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.	
Course Description: 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.	
Assumed Background: Multivariate Calculus, Topology of R^k	
Assessment methods: written exam	

Course Title: Electrodynamics of continuous media	Number of Units: 1	
SSD: ING/IND-31	CFU: 9	
Course aims: 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.		
Course Description Maxwell equations (eqs.) in vacuum and in presence of materials. Electromagnetic (e.m.) waves and radiation. Lagrangian formulation. Lorentz invariance. Balance of e.m. momentum, e.m. energy. Uniqueness of solution. Coupling of Maxwell's eqs. and thermodynamics of continuous media. Classification of media. Stationary and quasi-stationary fields. Mathematical aspects of stationary field equations. Conservative and solenoidal fields, Helmholtz decomposition, Tellegen theorem. Potential theory: differential and integral formulations. Special functions. Energy and forces in quasi stationary electromagnetic fields. Formulation of electrodynamics in terms of energy. Elements of electrodynamics in presence of ferromagnetic materials, dielectric materials, superconductors and semiconductors. Examples of e.m. systems relevant to applications.		
Assumed Background:		
Assessment methods: Oral interview and discussion of a case study		

Course Title: Electromagnetic Fields	Number of units: 1
SSD: ING-INF/02	CFU: 6

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.

Course Description: 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.

Assessment methods: Oral interview and discussion

Course Title: Geometric structures and Topology	Number of Units: 1
SSD : MAT03	CFU: 6
Course aims: The course aims to provide basic knowledge in General and Algebraic Topology, especially to students with an unsatisfactory background in Geometry.	
Course Description: Topological and metric structures. Compactness. Path connected spaces. Basic homotopy theory: deformations, retracts, homotopy equivalences. Fundamental group. Basic Homological Algebra. Singular homology groups.	
Assumed Background: Linear Algebra and Affine Geometry at undergraduate level	
Assessment methods: Oral examination.	

Course Title: Heat Transfer	Number of Units: 1
SSD : ING-IND11	CFU: 6
Course aims: 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.	
Course Description : Conduction: The governing equation. Steady one-dimensional heat conduction. Steady two-dimensional heat conduction. Transient conduction. Convection: The governing equations for: mass, momentum and energy transport. Forced and natural convection: boundary layer; boundary layer equations; dimensional parameters; external and	

internal flow; correlations. Radiation: Introduction. Processes and characteristics. Characteristics of real surfaces. Diffuse gray surface radiation exchange. Combined heat transfer mechanisms

Assumed Background: Basic knowledge of Thermodynamics and numerical methods.

Assessment methods: written exercises, oral test, and facultative homework project.

Course Title: Environmental Fluid Dynamics and Hydraulics	Number of Units: 1
SSD : ICAR/01	CFU: 6
Course aims: 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, 2 and 3 spatial dimensions. Numerical solutions by finite volume and finite difference methods will be developed for 1D and 2D models. Furthermore an introduction to transport problems of either a passive scalar quantity or an active one will be given.	
Course Description Introduction to the equations of unsteady water flow at different dimensionality, conservative and non conservative (classical) formulations. Discussion of dimensionality and resolution problems (DSV, SWE, RANS, DANS, LES, DNS). Hyperbolic property for 1D and 2D shallow water equations and its consequences. Focus on 1D and 2D problems to deal with large scale environmental flows. Characteristic method for the De Saint-Venant equations. Finite volume and finite difference discretization of model equations. Implicit and explicit schemes. Role and treatment of source terms, well balanced schemes and C-property. Riemann problems and approximate riemann solvers for the numerical flux evaluation. Introduction to scalar transport.	
Assumed Background: Numerical methods	
Assessment methods: Discussion on the computer implementation of a case study and oral examination	

Course Title: Information Theory	Number of Units 1
SSD : ING-INF/05	CFU: 6
Course aims: 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.	
Course Description: 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	
Assumed Background: A solid first course in probability is required. The course demands the motivation to deal with concepts that may be more abstract than the ones previously encountered	

Assessment methods:

Course Title: Mathematical Methods for Engineering	Number of Units: 1
SSD: MAT/05	CFU: 6
Course aims: Familiarise the student with the fundamental ideas and the main solving techniques for problems involving Fourier and Laplace transforms.	
Course Description: Complex number system. Functions of complex variable: holomorphic functions and conformal mappings; Cauchy-Riemann conditions and harmonic functions. Uniform convergence of sequences and series of functions, power series. Taylor series expansions. Laurent series expansions. Introduction to measure theory; Lebesgue measure and integral, main properties. Fourier transform and inversion formula; properties of the transform, convolution. Fourier series, convergence theorems. Laplace transform and inversion formula; properties of the transform, applications to differential models.	
Assumed Background: Mathematical Analysis II - Algebra and Geometry	
Assessment methods: Written and oral examination	

Course Title: Mathematical Physical Models	Number of Units: 1
SSD : MAT/07	CFU: 9
Course aims: 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.	
Course Description 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.	
Assumed Background: Calculus, Elementary Mechanics.	
Assessment methods: Oral examination	

Course Title: Mathematics for Cryptography	Number of Units: 1
SSD : INF01	CFU: 6
Course aims: 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.	
Course Description: 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); Carmichael 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-Hellman problem; the RSA protocol; elliptic curve cryptosystems; cryptanalysis

Assumed Background: Undergraduate level

Assessment methods: written dissertation and oral colloquium

Course Title: Mechanics of Vibrations

Number of Units: 1

CFU:6

SSD: IND-IND/13

Course aims:

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.

Course Description:

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.

Assumed Background

Assessment methods: Oral examination.

Course Title: Modern Physics	Number of Units: 1
SSD : FIS/01	CFU: 6
Course aims: acquisition of the fundamental aspects of the physics of 20-th century: special relativity, quantum mechanics, elementary particle physics, general relativity and cosmology	

Course Description: Special Relativity; The Quantum Theory of Light; The Particle Nature of Matter; Matter Waves; Quantum Mechanics in One Dimension; Quantum Mechanics in two and Three Dimensions; Atomic Structure; Statistical Physics; Elementary Particles Physics; General Relativity; Cosmology.
Assumed Background: elements of mechanics, thermodynamics and electromagnetism; elements of mathematical analysis and analytical mechanics
Assessment methods: oral exam

Course Title: Nonlinear Dynamics and Control	Number of Units: 1
CFU: 6	SSD: ING/INF-04
Course aims: The goal of this course is to introduce students to the foundations of the analysis and control of nonlinear systems and illustrate their most relevant applications in Science and Engineering.	
Course Description Nonlinear Systems: fundamental concepts and introduction; Lyapunov based control strategies; stability and passivity of input-output systems; Synthesis of Nonlinear controllers: perspectives and methodologies; Feedback Linearization; Hybrid and switched control; Adaptive Control; Introduction to Consensus and Synchronization of Network systems.	
Assumed Background: Nonlinear Systems	
Assessment methods: Oral examination and project work	

Course Title: Nonlinear Systems	Number of Units: 1
CFU: 6	SSD: ING/INF-04
Course aims: The aim of the course is to introduce students to the foundations of the mathematical theory of nonlinear systems and illustrate the theory via some representative examples from applications.	
Course Description: 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 (e.g. piecewise smooth systems, feedback linearization and control, distributed nonlinear systems)	
Assumed Background:	
Assessment methods: Oral interview and discussion of a case study	

Course Title: Numerical Methods	Number of Units: 1
CFU: 9	SSD: MAT/08
Course aims: The primary goal is to provide a basic knowledge of numerical methods, enabling students to work with mathematical models of technology and systems.	
Course Description 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,...).

Assumed Background: Linear Algebra at undergraduate level, multivariable calculus, some knowledge of problem solving environments (MATLAB, Python,...).

Assessment methods: Oral examination, written text

Course Title: Operational Research	Number of Units: 1
SSD: MAT09	CFU: 6
Course aims: The main objective of the course is the introduction of the students to the use of mathematical programming models and in particular to both linear and nonlinear optimization models (with both continuous and integer variables) and their applications in real world fields, including control, 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.	
Course Description: 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; Conjugate Direction Methods; Quasi-Newton Methods; Nondervative Methods. Optimization over a Convex Set; Lagrange Multiplier Theory; Lagrange Multiplier Algorithms.	
Assumed Background: Linear algebra: matrices, vectors, determinants, systems of linear equations. Vector analysis, eigenvalues and eigenvectors, quadratic forms and differential equations. Elements of convex analysis and optimality conditions.	
Assessment methods: Written Test and Oral Exam	

Course Title: Optoelectronics	Number of Units: 1
SSD : ING-INF/01	CFU: 6
Course aims: 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 of view. The course will present the basic concepts of integrated optics, including materials and fabrication technologies as well as the major integrated optical devices.

Course Description: The following arguments are the main topics of the course: Optical Wave Guided Theory - Channel waveguides and Fibre optics. Semiconductor Materials for integrated optics - Photodetectors and Integrated Lasers and LEDs – Passive and Active optoelectronic integrated devices. Some technological aspects on the fabrications of integrated optoelectronics devices. Examples of Applications.

Assumed Background: some basic concepts of electronic circuit theory; some basic concepts of quantum electronics; some basic concepts of solid state physics.

Assessment methods: 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.

Course Title: Partial Differential Equations	Number of Units: 1
SSD : MAT05	CFU: 6
Course aims: The course aims to provide basic knowledge of Partial Differential Equations, both needed to formulate mathematical models of engineering and scientific problems.	
Course Description: Laplace Equation: physical interpretation and probabilistic interpretation. Fundamental solution, Newtonian potential. Harmonic functions: mean value formula, maximum principle, Harnack inequality, Liouville theorem. Uniqueness of solutions of Dirichlet and Neumann problems for the Poisson equation. Regularity of harmonic functions. Green function. The Green function in a half space and the Green function in a ball. Variational formulation of Dirichlet problem for the Poisson equation. Heat Equation: physical and probabilistic interpretation. Existence of global solutions. Solution of nonhomogeneous problems via Duhamel principle. Mean value properties of solutions and maximum principle. Uniqueness of solutions. Infinite speed propagation of the data. Energy methods. Backward uniqueness. Transport equation: solutions of the homogeneous and nonhomogeneous problem. Wave equation: physical interpretation. Solutions of the 1-dimensional homogeneous wave equation: D'Alembert formula. Solutions of the 2 and 3-dimensional homogeneous wave equation. Solutions of the nonhomogeneous wave equation via Duhamel principle. Characteristic cone and finite speed propagation of the data. Energy methods and uniqueness of solutions. Separation of variables: solutions of the Poisson equation in special planar and 3-dimensional domains, solutions of the heat equation and of the porous media equation. Fourier transform and applications to Bessel potentials and solutions of the heat equation, the Schrödinger equation, the wave equation and the telegraph equation. Laplace transform and applications to the heat equation and the wave equation. Compact operators. Fredholm theory. Eigenvalues and spectrum of a compact operator. Eigenvalues of the Laplacian: variational definition and properties. Properties of eigenfunctions. Sobolev spaces: definitions, basic properties, $H=W$, approximation with smooth functions, extension domains, traces, imbedding theorems and compact imbeddings, Poincaré inequality. Weak solutions of elliptic equations. Existence of weak solutions. Existence of strong and classical solutions via regularity.	
Assumed Background: Mathematical Analysis at undergraduate level, basic knowledge of Real and Functional Analysis.	
Assessment methods: Oral examination	

Course Title: Real and Functional Analysis	Number of Units: 1
SSD : MAT/05	CFU: 9
Course aims: The course aims to provide basic knowledge of Functional Analysis required to formulate mathematical models of engineering and scientific problems.	
Course Description: Topological spaces. Metric spaces. Completeness. Compactness. Complete metric spaces: Banach spaces, Hilbert spaces. Orthonormal basis and Fourier series in Hilbert spaces. Linear and continuous operators between normed spaces. Compact operators. Adjoint operators. Spectral decomposition of self-adjoint 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.	
Assumed Background: Mathematical Analysis at undergraduate level	
Assessment methods: Oral examination	

Course Title: Signals Theory	Number of Units: 1
SSD : ING-INF/03	CFU: 6
Course aims: This course aims to provide methodological competencies regarding basic probability and random variables, deterministic and random signals in the time and frequency domain, and their processing through linear systems.	
Course Description: 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.	
Assumed Background: Undergraduate level	
Assessment methods: Oral examination	

Course Title: Solid State Physics	Number of Units: 1
SSD : FIS/03	CFU: 6
Course aims: fundamental aspects of solid state physics. Phenomenological and microscopic description of metals and semiconductors. Transport, thermodynamic and dielectric properties of solids.	
Course Description: 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 semiconductors. 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.	

Assumed Background: elements of thermodynamics and electromagnetism; Modern physics
Assessment methods: oral exam

Course Title: Statistical Methods for Industrial Process Monitoring	Number of Units
SSD : SECS-S/02	CFU: 6
Course aims: Statistical Methods for Industrial Process Monitoring is a methodological – applicative course whose aim is to train students on statistical tools for monitoring of complex technological systems. Applications and case studies are addressed to train students on Total Quality Management, to formulate and define strategies for quality control and monitoring in industry in order to support decision making process in a big data framework.	
Course Description <i>The Multivariate Quality-Control Problem.</i> 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. <i>Inference about mean vectors.</i> The multivariate normal distribution, the Wishart distribution, the F distribution. Hotelling T^2 test. Confidence regions and simultaneous comparisons of component means. The Bonferroni method for multiple comparisons. Family-wise Error Rate (FWER) and False Discovery Rate (FDR). Comparisons of several multivariate means. Inference for Linear Models. <i>Elements of classical Statistical Process Control.</i> Control Charts for variables. Control Charts for attributes. Number of samples and sampling frequency. Sample size and control effectiveness. Warning limits and CUSUM control chart, Moving Average control chart, EWMA control chart. Process Capability Analysis. Engineering examples through software environment R. <i>Engineering approach to modern Process Monitoring and Control.</i> The Hotelling T^2 Control Chart. The Multivariate EWMA Control Chart. Regression Adjustment. Control Charts for Monitoring Variability. Latent Structure Methods. Principal Component Regression (PCR). Partial Least-Squares (PLS). Regression control charts. Engineering examples through software environment R. <i>Introduction to Functional data analysis and control charts for statistical monitoring of functional data.</i> Functional data analysis. Statistical monitoring of functional data. Industrial case studies and applications.	
Assumed Background: Probability and Statistics	
Assessment methods: Individual written test and its oral discussion	

Course Title: Stochastic Processes	Number of Units: 1
SSD : MAT/06	CFU: 6
Course aims: To consolidate the fundamental contents of probability theory, in the first part of the course, some definitions and theorems are revisited by means of the formalism of the measure theory. The main purpose of teaching is to provide concepts, theorems, contents and tools that are the basis for both a more detailed study of the theory and for a conscious use in applications of stochastic processes.	
Course Description Conditional Means. Stopping times. Martingales and convergence results. Brownian motion and Brownian bridges. Some laws of Brownian motion. Analytical approach to Brownian motion. Stochastic integration. Ito formula and stochastic differential equations.	

Assumed Background: At least a basic course on probability theory.

Assessment methods: Oral examination.
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Course Title: Systems identification	Units: 1
SSD: ING-INF/04	CFU: 6
Course aims: 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.	
Course Description: 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: <i>Parametric estimation</i> . 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. <i>Bayesian Estimation</i> 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.	
Assumed Background:	

Assessment methods: oral exam

Course Title: Theory of Elasticity	Number of Units: 1
SSD : ICAR08	CFU: 9
Course aims: The basic concepts and the operative use of the finite element method in solving problems of linear elasticity by employing professional software is the main objective of the course. Practical applications are illustrated with reference to framed structures and more complex structural models such as membranes, plates and tridimensional solids. Modeling approaches and validation techniques of numerical results are discussed. .	
Course Description: Thermodynamics: Course Description 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 mono-, bi- and tri-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. Domain discretization. Displacement field discretization. Procedures for assigning shape function and relevant properties. Formulation of finite element formulation in local reference frames. Iso- and lpo-parametric transformations. Element distortion and shape ratios. Numeric integrations: Gauss quadrature. Load and mass vectors. Assemblage of equations and assignment of restraints. Evaluation of support reactions. The finite element method applied to static analysis of: Trusses: modeling of a metal space truss roof. Framed structures: modeling of a bicycle frame. Membranes. 2D triangular and quadrilateral elements, axial-symmetric, plane stress and plane stress state: modeling of a rotor of a micro-engine. Tridimensional (3D) structures: tetrahedral and hexahedral elements. Modeling techniques: mesh density and element distortion. Compatibility between meshes with several element formulations: transition elements. Assignment of symmetry conditions (plane, spherical, axial, cyclic). Modeling of offsets, restraints (global and local), nodes shared by elements with different formulation. Advanced problems of finite element analysis: the patch test, locking problems, subintegration and hourglassing.	
Assumed Background: Tensor calculus and Continuum Mechanics	
Assessment methods: illustration of the developed finite element models, oral exam	

Course Title: Thermodynamics and Transport Phenomena	Number of Units: 1
SSD : ING-IND/22	CFU: 9
Course aims: The Course presents the basis of physical and mathematical description of Thermodynamics and Transport Phenomena from a microscopic point of view.	
Course Description: Thermodynamics: Review of Thermodynamics for homogeneous and piecewise homogeneous systems. Role of constitutive equations. Introduction to (classical) Statistical Mechanics: basic laws and selected applications (e.g., derivation of equilibrium constitutive equations). Nonhomogeneous systems: general balance equations for their thermodynamics. Transport phenomena: Microscopic approaches to the (classical) dynamics of nonhomogeneous systems. Boltzmann equation, Smoluchowsky equation, multiparticle simulations. Selected applications: fluids, polymeric liquids, liquid crystals.	
Assumed Background:	
Assessment methods:	

Course Title: Waves	Number of Units: 1
SSD : ING-IND/06	CFU: 6
Course aims: 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.	
Course Description: 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.	
Assumed Background: Mathematical Physics Models	
Assessment methods: Oral examination	