DOCTORATE COURSE IN ENGINEERING

SCHEDULED TEACHING

Academic Year 2024 - 2025
LX Cycle

Curriculum:
Industrial Engineering;
Information Engineering;
Civil Engineering and Architecture

Educational offer and breakdown into CFU

The overall commitment is 180 training credits, evenly distributed over the three years of the course (60 CFU for each single year). The provision of 1 CFU corresponds to 6 hours of frontal teaching provided.

The training activity involves the acquisition of **21** total CFU of which 13 (equal to 78 hours) of classroom teaching provided in cycles of lessons specifically offered by the University of Messina. The use of classroom teaching can also take place in telematic mode for PhD students who carry out research periods at foreign institutions foreseen in their research project and previously authorized by the Board. Attendance at the course will be certified by the teacher. Only for PhD students who, being in countries with a different time zone, are unable to follow the teaching provided also in telematic mode, alternative training activities can be provided, previously authorized by the Board with an appropriate request, useful for the acquisition of mandatory training credits.

The CFU must be obtained by attending lessons and in-depth seminars in the common disciplinary areas (SSD) or in the individual curricula supported by linguistic and IT improvement activities. Part of the teaching activities will be dedicated to the in-depth study of the issues concerning the valorization and dissemination of results, intellectual property and open access to data and research products, as well as the management of research and knowledge of European and international research systems.

The remaining number of training credits (n. **159** CFU) is assigned by the teaching staff to activities connected with the specific research of individual doctoral students, including participation in conferences, seminars, schools, stays abroad and thesis writing activities.

Specifically, the training credits are distributed as follows:

- frontal teaching activities: n. **13** CFU
- Mandatory complementary training activities (linguistic, IT, management, etc.): n. **8** CFU
- Participation in research-related activities chosen by the PhD student: participation in conferences, congresses; Erasmus or other type of stays abroad; publications; tutoring activities; supplementary teaching activities: n. **14** CFU

- individual research activity, to be illustrated and discussed in the annual report for the transition to the years following the first: n. **117** CFU
- thesis writing: n. **28** CFU

The following criteria will be used to assign training credits to the activities freely chosen by the PhD student:

- Participation in a conference, congress or seminar (n 0.5 CFU/day of participation) in accordance with the SA Resolution of 23/12/2013
- Participation in a conference, congress or seminar as a speaker (n. 1 CFU/day of participation)
- Erasmus or other type of research stay abroad (n. 1 CFU/month of stay abroad) in accordance with the SA Resolution of 21/12/2018
- Attendance at specialization courses or certifiable training activities connected with the training and research activity of the doctoral student will be assessed by the Teaching Board for the purposes of assigning training credits and quantifying them on the basis of the indications provided by the organizer.
- The publication of scientific articles in journals, essays in volumes, book chapters or monographs, for which the date of acceptance of the contribution or the publication of the volume will be valid, will be evaluated by the teaching council for the purposes of assigning training credits and quantifying them (from 1 CFU for publication in a national or unlisted journal to 5 CFU for publication in an ISI or Scopus journal of class Q1 or A).
- The tutoring activity of students in the Bachelor's and Master's degree courses of the University of Messina, subject to the approval of the Teaching Board, may be evaluated for the purposes of assigning training credits and quantifying them (1 credit every 8 hours; up to a maximum of 5 CFU per academic year)
- The supplementary teaching activity, always within the maximum cumulative limit of 40 hours per year and subject to approval by the Teaching Board, may be evaluated for the purposes of assigning training credits and quantifying them (1 CFU for every 5 hours of supplementary teaching up to a maximum of 4 CFU).
- Excess training credits will not be counted towards reaching the annual threshold.

The Board of the Doctoral Course in Engineering approves the teaching activities associated with each year of the course (Activity Plan)

There are no exams/assessments with suitability by individual teachers. The credits relating to institutional courses are specified in the annual Manifesto degli Studi and are valid in the year in which the course is attended.

The official language is Italian, however courses may be held in English if there are foreign students.

The calendar of the lessons will be advertised on the PhD WEB page https://engineering.phd.unime.it/it in the Teaching provided section.

In order to comply with the current legislation, relating to mandatory training (pursuant to art. 36 and 37 of Legislative Decree 81/08 and subsequent amendments), PhD students who do not have other safety certifications issued by the University of Messina are required to participate in the General Training Course

on Workplace Safety lasting 4 hours, with a learning assessment test, in telematic mode, accessible at the following address: https://moodle2.unime.it/course/view.php?id=48659 through institutional credentials (codicefiscale@studenti.unime.it) on the Moodle platform.

The scheduling of training credits as described is reported, by course year, in the following table.

Activity Plan

YEAR	Mandatory educational offer (CFU)	Optional educational offer (CFU)	Total hours of classroom teaching provided (h)	Mandatory complementary training activities (linguistic, IT, management, etc..) (CFU)	Other activities (Seminars, Congresses, ERASMUS, articles, etc…) (CFU)	Research activities (CFU)	Thesis writing	TOTAL (CFU)
THE	4	1	30	7	3	45	0	60
II	2	3	30	1	7	47	0	60
III	1	2	18	-	4	25	28	60
TOTAL	7	6	78	8	14	117	28	180

List of teaching provided and other teaching activities 1st year (1 CFU of your choice)

Type of activity	Activity/teaching name	Curriculum	Tongue	CFU	SSD	Hours Frontal lesson
Mandatory teaching activity (4 CFU)						
	DOE (Design of Experiments) and statistical analysis of experimental data	Everyone	English	1	ING/IND 16	6
	Hardware and Software for data acquisition and processing	Everyone	English	1	ING/INF 01	6
	Mathematical models for engineering	Everyone	English	1	MAT/07	6
	Ecological and digital transition (Materials and Technologies for the circular economy)	Everyone	English	1	ICAR/10	6
Elective educational activity (1 CFU)	Polymer matrix nanocomposites	Industrial Eng.	English	1	ING/IND 22	6
	Technologies and sensors for industrial applications	Industrial Eng.	English	1	CHEM/07	6
	Mechanical gears vs magnetic gears	Industrial Eng.	English	1	ING/IND 13	6
	Innovative structures made of ropes to overcome large spans	Civil Engineering and Architecture	Italian	1	ICAR/09	6
	Sustainable management of cultural heritage	Civil Engineering and Architecture	Italian	1	ICAR/17	6
	Discrete event simulation	Eng. Information	English	1	ING-INF/05	6
	Programming Programmable Logic Controllers (PLC)	Eng. Information	English	1	ING-INF/04	6
	Networks and protocols for Industry 4.0	Eng. Information	English	1	ING/INF 03	6
Mandatory complementary training activities (linguistic, IT,						
	Computer skills acquisition activities[1]	Everyone		2		12
	Language improvement activities[2]	Everyone		3		18
	Application of a research proposal for Marie Sklodovska Curie Actions Post Doctoral Fellowship: drafting, testing and management[3]	Everyone	English	1		6
	How to write a scientific paper[4]	Everyone	English	1		6

management, etc..) **(7 CFU)**						
	TOTAL			**12**		**72**

Verification procedures for admission to the following year

At the end of the academic year, for admission to the following year, the doctoral student is required to present to the Teaching Board a report on the research activity carried out and the results achieved. The Teaching Board may decide that the report must be integrated with an oral presentation and, possibly, with an interview.

[1]The activities include the acquisition of IT skills related to research, especially software (databases; indexing programs; content analysis programs; statistical processing programs – MATLAB, SPSS; image processing programs – Indesign Adobe; X press). It is planned to organize, in agreement with the other doctorates of the University, IT improvement activities (courses and/or seminars) on operating systems, programming also with advanced/integrated languages of scientific programming. The doctoral students will also have the opportunity to participate in seminars and refresher/training courses organized by the companies supplying scientific equipment and IT support for research activities.

[2] All PhD students will be encouraged to take exams that allow them to obtain internationally recognized certificates, also by using the ROSETTA STONE platform, made available by the University. In this regard, knowledge of the English language, which is essential for research and technical-scientific study activities at an international level, is specifically assessed during the entrance exam. PhD students will also find themselves carrying out research and in-depth studies on bibliographic sources in English, speaking at international conferences and drafting reports and technical-scientific works in English.

[3] Seminar organized and delivered by College teachers or external teachers

[4]Seminar organized and delivered by College teachers or external teachers

List of teaching provided and other teaching activities II year (3 CFU to choose from)

Type of activity	Activity/teaching name	Curriculum	Tongue	CFU	SSD	Hours Frontal lesson
Mandatory teaching activity (2 CFU)	Stochastic Models and Monte Carlo Simulations	Everyone	English	1	ICAR/02	6
	Decision making techniques	Everyone	English	1	ING-IND/17	6
Elective educational activity (3 CFU)	Innovative welded joints for marine applications	Industrial Eng.	Italian	1	ING-IND/02	6
	Metallurgy of titanium alloys and additive manufacturing techniques	Industrial Eng.	Italian	1	ING/IND 21	6
	Innovative catalytic processes for energy production and environmental protection	Industrial Eng.	Italian	1	CHEM/04	6
	Advanced biomass conversion processes for energy production and mobility	Industrial Eng.	Italian	1	CHEM/07	6
	ITS systems for logistics	Civil Engineering and Architecture	Italian	1	ICAR/05	6
	Experimental and numerical methods for the study of hydro-morphodynamic processes	Civil Engineering and Architecture	Italian	1	ICAR/01	6
	Behavior of geotechnical systems subjected to seismic actions: analysis of safety conditions and performance evaluation	Civil Engineering and Architecture	Italian	1	ICAR/07	6
	Urban regeneration	Civil Engineering and Architecture	Italian	1	ICAR/20	6
	Electrical characterization of devices and materials	Eng. Information	English	1	ING/INF 01	6
	Edge and Fog Computing Principles	Eng. Information	English	1	ING/INF 05	6
	Identification of nonlinear dynamical systems	Eng. Information	English	1	ING-INF/04	6
	Cybersecurity in cyber physical systems	Eng. Information	English	1	ING/INF 05	6
Complementary training activities	Valorisation and dissemination of results, intellectual property and open access to research data and products		English	1		6

(linguistic, IT, management, etc..) **(1 CFU)**						
	TOTAL					**36**

Verification procedures for admission to the following year

At the end of the academic year, for admission to the following year, the doctoral student is required to present to the Teaching Board a report on the research activity carried out and the results achieved. The Teaching Board may decide that the report must be integrated with an oral presentation and, possibly, with an interview.

List of teaching provided and other teaching activities III year (2 CFU to choose from)

Type of activity	Activity/teaching name	Curriculum	Tongue	CFU	SSD	Hours Frontal lesson
Mandatory teaching activity (1 CFU)	Innovation and technology transfer	Everyone	English	1	ING-IND/35	6
Elective educational activity (2 CFU)	Environmental sustainability through product life cycle analysis	Industrial Eng.	English	1	ING/IND 15	6
	Experimental techniques and finite element analysis for the industrial sector	Industrial Eng.	English	1	ING/IND 14	6
	Models and techniques for risk assessment for a sustainable industry	Industrial Eng.	English	1	ING-IND/25	6
	Modeling uncertainties in building materials and calculating the response of structures	Civil Engineering and Architecture	Italian	1	ICAR/08	6
	BIM approaches for design and maintenance management of transport infrastructure	Civil Engineering and Architecture	Italian	1	ICAR/04	6
	Sustainability and resilience of urban drainage systems: SUDS	Civil Engineering and Architecture	Italian	1	ICAR/02	6
	Evolution and Applications of Reconfigurable Digital Systems: From the Apollo Guidance Computer to FPGA Devices	Eng. Information	English	1	ING/INF01	6
	Decarbonisation of the electricity system	Eng. Information	English	1	ING-IND/32	6
	Estimation of measurement uncertainty in experimental activities	Eng. Information	English	1	ING-IND/12	6
	TOTAL			**2**		**12**

COMPLETE LIST OF FIRST YEAR COURSES WITH DESCRIPTION

Activity/teaching name	SSD*	Hours of frontal lesson*	CFU	Description	TYPE	CURRICULUM
DOE (Design of Experiments) and statistical analysis of experimental data	ING/IND 16	6	1	Objectives: The course recalls basic concepts of statistics, statistical analysis of data and planning of experimental plans, with the aim of providing a reading and practical use tool for those who approach research. Doctoral students will acquire the technical terminology and learn to use a software for data processing. They will be able to define an experimental plan, identifying the factors and levels of variability and then analyze whether there is an effect of the factors and any interactions between them through the analysis of variance. Contents What is Design of Experiment and what is it for? Factors and levels. Factorial designs. Analysis of variance (ANOVA). Experiments with one factor and with multiple factors. Using Minitab® Software - Examples of analysis of variance on experimental data, with one factor and with two factors. Examples on the evaluation of the interaction. Representation of statistical data (histograms, diagrams, boxplots, etc.).	MANDATORY COURSE	EVERYONE
Hardware and Software for data acquisition and processing.	ING/INF 01	6	1	Goals The module focuses on hardware and software aspects related to data acquisition and processing systems with applications in the field of electronic measurements. Course contents Introduction to digital signal processing; fundamentals of data acquisition systems; fundamentals of measurement instrumentation, interfaces and DSA/DAQ acquisition cards; software for data acquisition, processing and plotting; numerical algorithms for the calculation of integrals, numerical filtering and spectral analysis.	MANDATORY COURSE	EVERYONE
Mathematical Models for Engineering	MAT/07	6	1	The aim of the course is to provide the main mathematical tools useful for solving mathematical models described by partial differential equations of interest in engineering applications. Contents: Quasilinear, semilinear, linear partial differential equations. Balance laws. First order equations: method of characteristics. Transport of pollutants in rivers and a traffic model. Classification of second order equations: hyperbolic, parabolic, elliptic. Characteristic curves and canonical form of second order partial differential equations. Wave phenomena. Vibrating string equation: D'Alembert solution Mixed-type problem: Method of separation of variables.	MANDATORY COURSE	EVERYONE
Ecological and digital transition (Materials and Technologies for the circular economy)	ICAR/10	6	1	The aim of the course is to provide PhD students with basic knowledge on sustainable materials, techniques and construction processes needed to give the building envelope better performance in relation to well-being needs and allow adjustments in line with European	MANDATORY COURSE	EVERYONE

				objectives in terms of circular economy. With reference to vertical, opaque and transparent closures, particular reference will be made to construction solutions that meet the indications of CAM Edilizia 2022 and in line with the objectives of the 2030 Agenda for Sustainable Development, looking at the entire life cycle of the resources used and the reduction of emissions and waste. Contents - Vertical, opaque and transparent closures: functional solutions and technical alternatives - The technological evolution that has affected the solutions for energy saving of the building envelope: conventional insulating materials (mineral, animal, vegetable, synthetic, composite) and non-conventional (VIP, heat-reflecting, aerogels, phase change materials) - Technological innovation of window solutions to optimize optical and energy response: mixed and disassembled windows, warm edge channels, static glass filters (absorbent, reflective, low-emission, selective, TIM), dynamic (chromogenic, angular selectivity), modular (mechanical, optical, electrical systems) - Performance assessment of buildings; national and international sustainability protocols		
Polymer matrix nanocomposites	ING/IND 22	6	1	Course Description The course aims to deepen the basic knowledge of polymer matrix composite materials that can be used in advanced industrial applications. Particular emphasis will be given to aspects related to the design, development and industrialization of materials. Composite materials and nanocomposites. Polymer matrices. Reinforcing fillers. Physical and chemical compatibilization. Physical-mechanical properties. Characterization techniques. Production technologies. Engineering applications of polymer matrix nanocomposites.	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Technologies and sensors for industrial applications	CHEM/07	6	1	Goals The main objective of the course is to provide the student with fundamental knowledge on sensor technologies. Particular attention will be paid to the specifications of sensing systems and transduction platforms, as well as to the design/realization methodologies of sensors for various applications. Course contents Characteristics of different types of sensors. Operating principles. Semiconductor sensors: Resistive temperature sensors (RTD, NTC Thermistors, PTC Thermistors), resistive light radiation sensors (LDR), resistive gas sensors, liquid sensors; capacitive sensors. Electrochemical sensors. Biosensors. MEMS sensors. Wearable sensors.	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Mechanical gears vs magnetic gears	ING/IND 13	6		Goals The aim of the course is to stimulate the student to a broader vision of a problem such as the transmission of motion treated in the descending courses of study (bachelor's and master's degrees) in order to make him acquire a critical modus operandi with innovative solutions to solve new problems. Course contents Starting from the knowledge of the most used mechanical gears, we will analyze the gears that exploit the presence of a magnetic field to allow the transmission between a mover and a follower. We will highlight the advantages and disadvantages of one and the other solution and we will evaluate the possible applications in the field of micro-mechanics and robotics.	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Innovative structures made of	ICAR/09	6	1	Structures made of cables have always been a constant in the history of men, in the past	COURSE OF	CIVIL ENGINEERING

ropes to overcome large spans				natural materials such as wood and vegetal ropes were used. In countries with little industrialization, the suspension bridge of metal cables and wooden deck is a rule not the exception, even to overcome modest spans. The course aims to provide students with advanced knowledge on the problems related to the design and planning of large roofs and long-span bridges and viaducts, with particular attention to the use of innovative technologies and materials, since, with the increase in spans and heights of piers, the designer must refine the analysis strategies and the verification criteria in terms of safety and functionality. Likewise, in highly industrialized countries, the roofs of large stadiums, shopping centers, sports halls and long-span bridges use the same technique to advantage. In fact, it is known that for the same covered surface area and/or span, structures supported by ropes are much lighter than traditional ones. What is provided for by the procedures codified by the codes is not exhaustive in this case and must be extended with particular attention to the size of the work analyzed. Furthermore, increasingly sophisticated innovative technologies must be used for the assembly of the designed works. The analyses must be conducted with particular attention to those phenomena that can be neglected for ordinary structures to ensure their appropriate resilience. The models are enriched with details that cannot be treated with the required completeness in classical design and in basic courses of level I and II.	YOUR CHOICE	AND ARCHITECTURE
Sustainable management of cultural heritage	ICAR/17	6	1	The topic of knowledge and sustainable management of architectural and urban heritage, in function of the social, economic and cultural development of a territory, has always been at the center of studies and projects related to its future. In some cases, the objective of understanding the stratifications that characterize cities and the architecture that is part of them, relating the current structure to the original one and to the transformations undergone over the centuries is particularly complex if carried out exclusively with traditional survey tools. It therefore becomes essential to integrate the transdisciplinary dimension of the topic discussed and digital tools that open up increasingly hybrid perspectives to respond to the needs of knowledge, documentation and dissemination of the cultural and identity value of each place or artifact. Contemporary methodologies of integrated survey and 3D modelling are therefore configured as tools of absolute importance to be used not only for the documentation of cultural heritage but also, thanks to the high metric precision, to formulate reconstruction or completion hypotheses of historical buildings with a strong cultural impact. At the same time, the preliminary stage of research always remains the archival and bibliographical investigation that aims to retrace the salient phases of the design process and that constitutes an essential basis to be implemented with new digital methodologies in order to create products useful for the promotion of cultural heritage on a rigorous scientific basis but also shareable with a heterogeneous public.	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE
Discrete event simulation	ING/INF 05	6	1	Objectives: To provide the fundamentals of the structure of a discrete event simulator and the statistical basis for the analysis and interpretation of the data it produces. Contents: Structure of a discrete event simulator. Random number generators; . Simulation models. Output analysis for a single model; definition of the measures of interest of the simulation model. Estimation of a probability measure. Estimation of the confidence interval. Output analysis for the forward simulation. Output analysis for the steady-state simulation. Definition of the test plan. Definition and verification of the measurement campaign	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Programming Programmable Logic	ING-INF/04	6	1	The course introduces the programming of Programmable Logic Controllers (PLC). After	COURSE OF	INFORMATION

Controllers (PLC)				defining the structure, functionality and programming languages, using the Zelio PLC from Scheider Electric, programs will be developed in Ladder and FBD language. Programs that implement basic functions such as analog and digital inputs and outputs, auxiliary relays, timers, analog comparisons and counters will be tested on the PLC.	YOUR CHOICE	ENGINEERING
Networks and protocols for Industry 4.0	ING/INF 03	6	1	Objectives: The main objective of the course is to provide the student with basic knowledge of networks and the main communication standards and protocols used for data transmission in industrial environments; particular emphasis will be given to research activities in this context. Course contents: Evolution of data networks for industrial control and automation (from fieldbuses to the Industrial Internet of Things); requirements of networks for industrial applications; architecture and functionality of data transmission systems for industrial environments; wireless technologies and protocols for Industry 4.0; research activities in the field of the Industrial Internet of Things.	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Computer skills acquisition activities		12	2	The integration between solid basic preparation and understanding and use of the most advanced information technologies is a fundamental element of the doctoral course, essential to produce the skills needed to understand technological evolution, interpret its contents, identify its applications, expand and modify the way of operating. The activities include the acquisition of IT skills related to research, especially software (databases; indexing programs; content analysis programs; statistical processing programs – MATLAB, SPSS; image processing programs – Indesign Adobe; X press).	MANDATORY COMPLEMENTARY TRAINING ACTIVITIES (LINGUISTICS, COMPUTER SCIENCE, MANAGEMENT, ETC..)	EVERYONE
Language improvement activities		18	3	The specific objectives of this teaching activity are: - provide secure oral and written linguistic-technical skills; - enable students to use tools for communication and information management; - help students learn to learn new foreign languages by becoming increasingly autonomous in controlling their own learning process and consolidating their linguistic and professional skills; - help students acquire transversal skills - soft skills (cognitive, relational, realization, etc.) to foster creativity, flexibility, public speaking, organizational skills and team spirit; as well as the ability to solve problems, in order to facilitate their entry into the world of work. The linguistic improvement activities will be carried out using the ROSETTA STONE software, made available by the University (with the relative certificate of linguistic competence pursued). In this regard, knowledge of the English language, essential for research and technical-scientific study activities at an international level, is specifically assessed during the admission exam.	MANDATORY COMPLEMENTARY TRAINING ACTIVITIES (LINGUISTICS, COMPUTER SCIENCE, MANAGEMENT, ETC..)	EVERYONE
Application of a research proposal for Post Doctoral Fellowship Marie Sklodovska Curie Actions: drafting, testing and management.		6	1	Goals The course aims to analyze in detail the characteristics of the Marie Sklodowska Curie Postdoctoral Fellowship action and to identify guidelines for writing a competitive project proposal. Furthermore, the course aims to provide students with the tools for the scientific and administrative management of the project through a case study concerning the design and production of perovskite materials for solar energy storage. Course contents Introduction to the Marie Sklodowska Curie Actions Post Doctoral Fellowship: Work Programme, objectives, defining elements, eligibility criteria and budget. International, interdisciplinary and intersectoral mobility. Tools and guidelines for the preparation of a competitive project proposal: Excellence, Impact and Implementation sections. The researcher's CV. Evaluation process. Management of a MSCA project through a case study.	MANDATORY COMPLEMENTARY TRAINING ACTIVITIES (LINGUISTICS, COMPUTER SCIENCE, MANAGEMENT, ETC..)	EVERYONE

How to write a scientific paper		6	1	Goals The measure of a researcher's productivity is based fundamentally on the number of articles published. This productivity is the basis of many evaluations ranging from career progression to requests for funding. The quality of productivity is often also evaluated based on the prestige of the journals where the publication takes place. The road to publication is rarely straightforward; few journals provide practical guidance to researchers who are struggling to publish their data. The goal of this seminar is to provide key tools for navigating the practical steps in each part of the publication process and successfully getting your work accepted. Description The seminar illustrates the various phases of the process of developing, drafting and finalizing a scientific article, indicating the methods of correct presentation of the research results and highlighting which aspects require particular attention. A specific focus is placed on the aspects related to the so-called "plagiarism" and in particular to self-plagiarism.	MANDATORY COMPLEMENTARY TRAINING ACTIVITIES (LINGUISTICS, COMPUTER SCIENCE, MANAGEMENT, ETC..)	EVERYONE

COMPLETE LIST OF 2ND YEAR COURSES AND DESCRIPTION

Activity/teaching name	SSD*	Hours of frontal lesson*	CFU	Description	TYPE	CURRICULUM
Stochastic Models and Monte Carlo Simulations	ICAR/02	6	1	Goals The course aims to provide fundamental notions on the analysis of time series and on the theory of stochastic processes. In particular, the topic of the adaptation of stationary stochastic models to data samples for the generation of synthetic series through Monte Carlo simulation techniques will be addressed. In addition to the theoretical aspects, numerical examples in Matlab environment will be proposed through which the doctoral students will acquire the basic knowledge to select the models to be applied to the solution of typical engineering problems. Course contents Introduction to time series analysis. Trends, jumps and seasonality in time series. Memory of a process. Concept of stationarity and ergodicity. Expected value, variance, autocovariance and autocorrelation. Independent and identically distributed stationary models. White noise. Gaussian stationary models. ARIMAX autoregressive and moving average stationary models. Monte Carlo simulation methods. Applications in Matlab.	MANDATORY COURSE	EVERYONE
Decision making techniques	ING-IND/17	6	1	The aim of the course is to provide students with the basic concepts of multi-criteria decision-making techniques. The student will be able to evaluate different alternatives on the basis of multiple aspects that are often in conflict with each other and to make a choice and/or an ordering among them. Finally, an overview of the main multi-criteria techniques is provided. Contents:	MANDATORY COURSE	EVERYONE

				- Introduction - Classification of multi-criteria methods: (Multi-Objective Decision- Making vs Multi-Attribute Decision- Making, Compensatory and non-compensatory methods, utility theory, hierarchical analysis and outranking techniques) - The main decision making techniques divided into choice, sorting and clustering methods - The Weighted (WS) Method - The normalization - The Analytic Hierarchy Process (AHP) - Exercise		
Innovative welded joints for marine applications	ING/IND 02	6	1	Goals The course aims to provide an in-depth study of the main structural problems and knowledge relating to materials and joint techniques used in construction; - Particular emphasis will be given to the acquisition of competence and mastery in the scientific method of investigation through the analysis of laboratory tests and finite elements; - The course also aims to provide and stimulate the use of appropriate technical language in an advanced manner by examining the topic in depth through the evaluation of case studies.	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Metallurgy of titanium alloys and additive manufacturing techniques	ING/IND 21	6	1	Goals The aim of the course is to study in depth the issues concerning titanium metallurgy in relation to recent additive manufacturing techniques such as Laser Beam Melting (LBM) and Electron Beam Melting (EBM), with reference to the peculiar microstructural characteristics of the process and the possible formation of defects. The course therefore aims to provide the cognitive tools and skills necessary to define the mechanical properties of titanium alloy products produced using new additive technologies, optimizing their performance based on an appropriate choice of printing parameters and any pre- or post-process treatments. In this perspective, the most recent studies aimed at simulating thermal fields induced by mobile sources will also be explored in depth. Contents -Metallurgy of titanium alloys, α-stabilizing and β-stabilizing elements, transition temperature, effects of cooling rate. Behavior at high temperatures. -Additive manufacturing techniques: LBM and EBM, process parameters. -Analytical methods for the simulation of thermal fields induced by mobile sources.	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Innovative catalytic processes for energy production and environmental protection	CHEM/04	6		Course Objectives. The aim of the course is to provide the student with the scientific basis for understanding catalytic phenomena, characteristics and functionality of heterogeneous catalytic materials for innovative applications in the energy and environmental fields. In particular, the course aims to provide the student with a series of examples of applications of new catalytic systems based on metal oxides for the purification of wastewater and the production of "clean hydrogen". Course Contents. 1) Catalysis and Catalysts: Theoretical principles of catalytic phenomena and Fundamental properties of heterogeneous catalysts; 2) Development of new heterogeneous catalysts for environmental protection and energy applications; 3) Purification processes of industrial wastewater and hydrogen for energy applications.	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Advanced biomass conversion processes for energy production and mobility	CHEM/07	6		Goals The main objective of the course is to provide the student with the fundamental knowledge about the current technologies of transformation of plant biomass for the generation of bioenergy and for the production of bio-chemicals and bioplastics. The course also aims to provide the student with the tools to rationally develop selection criteria for the use of the	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING

				principles of green chemistry in the context of such conversion processes. Course contents Introduction to the concept of biomass. Types of biomass. Main components of plant biomass. The concept of Biorefinery. Pretreatment technologies of plant biomass. Combustion characteristics of ligncellulosic plant biomass and thermochemical processes for its conversion into bioenergy: gasification, pyrolysis and pyrogasification. Conversion of plant biomass mediated by chemical catalysts: the role of green chemistry; platform molecules for the production of biofuels, bio-chemicals, biomaterials; biodiesel. Notes on biochemical conversion processes of plant biomass. Industrial companies engaged in the valorization of plant biomass: some examples.		
ITS systems for logistics	ICAR/05	6	1	The course will provide the theoretical basis for the development of ITS (Intelligent Transport Systems) and the related implications in the logistics sector, in order to simplify and support the optimization of information and the management of warehouse and/or shipments, through interoperable and interconnected solutions. The data structures and the different types of information and real-time measures used for travel planning and logistics chain optimization will be analyzed and the modern simulation tools to be used in the planning, design and operation of such systems will be studied, considering the new technologies supporting the movement, storage and distribution of goods. The teaching will address the methodological bases of road terotechnology, with particular reference to the state of the art and current practice for the survey of quality indicators of road pavements. In particular, recent advances in the sector for the automated recognition of surface degradation through computer vision techniques and image analysis for the identification of geometric characteristics and the localization of the main deteriorations (such as cracks and holes) will be explored.	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE
Experimental and numerical methods for the study of hydro-morphodynamic processes	ICAR/01	6	1	Through the study of dimensional analysis and similarity, the course aims to provide knowledge on the application of laboratory physical modeling and to acquire sensitivity and mastery regarding the execution of experimental tests and the detection of the most common hydraulic measures. Numerical techniques for solving fluid mechanics equations applied to the hydraulics of natural systems will also be explored in depth, with reference to finite element meshing techniques and some open-source software, identifying numerical simulation codes in the main activities relating to the sector of river and maritime hydraulics. The choices that allow the identification of the main types of both physical models, with fixed and mobile bottom, and numerical ones will then be discussed, discussing their use to support both the design and construction of hydraulic works and the study of hydro-morphodynamic processes.	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE
Seismic Behavior of Geotechnical Systems: Analysis of Safety Conditions and Performance Evaluation	ICAR/07	6	1	Objectives The main objective of the course is to provide students with knowledge on the methodologies for analyzing the safety conditions of some geotechnical systems and on the procedures for evaluating their performance. The methodologies and procedures will be described with reference to some classic problems of seismic geotechnical engineering ranging from the problem of seismic stability of the construction site to the analysis of the behavior of the works. In particular, the aspects related to the effects of the behavior of the soils in conditions of cyclic and dynamic loading and their effects on the conditions of stability and post-seismic functionality of the geotechnical systems will be examined. The effects of the characteristics of the reference seismic motion on the performance and post-seismic functionality of the system and the implications on the selection criteria of the reference seismic actions for the analysis will also be examined.	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE
Planning and design tools for urban regeneration	ICAR/20	6	1	The course aims to deepen the basic knowledge of urban planning, with particular reference to urban regeneration actions, both within the implementation planning and within urban projects (eco-districts, positive energy districts, ville du quart d'heure, etc.). Doctoral students will acquire skills useful for understanding the new paradigms aimed at:	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE

				- designing settlements that can adapt to transformations and reduce human impacts on the ecosystem through a proactive approach aimed at building adaptive and resilient strategies (e.g. Global Public Space Program - Public Space Site-specific Assessment); - management of urban regeneration and economic development processes, based on forms of public-private partnership and active involvement of local communities.		
Electrical characterization of devices and materials	ING/INF 01	6	1	Objectives: When evaluating the quality of materials or the reliability of devices, it is important to have rapid, non-destructive, accurate and easy-to-implement electrical characterization techniques. The aim of the module is to provide knowledge of the most used techniques for the electrical characterization not only of devices but also of materials in general, ranging from the simplest current-voltage characterizations to more sophisticated techniques such as low-frequency noise measurements and impedance spectroscopy. Contents: physical principles underlying characterization techniques; main benchtop measurement instruments with reference to the design methods of dedicated instrumentation; examples of applications related to different sectors (electronics, medicine, food safety, environmental monitoring). Characterization, design and analysis of active and passive electronic devices, components and systems from low to very high frequencies. Innovative electronic technologies for the acquisition and processing of signals in wired and wireless systems. Evaluation of the impact of new technologies in relation to the social and environmental context	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Edge and Fog Computing Principles	ING/INF 05	6	1	Objectives: Introduce the concepts of fog and edge computing applied to smart cities and industrial systems 5.0. Present the Arancino architecture and reference products. Show the integration of different services within a single programming and management environment. Topics: Aspects of resource sharing at both hardware and software levels and distributed programming will be addressed. The Stack4Things platform and related programming techniques will be introduced. Some use cases of both smart cities and innovative factories will be presented where it was possible to integrate solutions and services from different suppliers using common APIs and shared dashboards.	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Identification of nonlinear dynamical systems	ING-INF/04	6	1	Objectives: The course aims to provide basic knowledge on the techniques for identifying dynamic, linear and nonlinear models of industrial processes, starting from experimental data. Contents: Design of experiments; data preprocessing; identification phases; model classes; identification with prediction error minimization; identification through machine-learning techniques; model validation; case studies.	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Cybersecurity in cyber physical systems	ING-INF/05	6	1	The course aims to provide students with the theoretical, mathematical and technological bases necessary to move with awareness in the world of Cyber Security. In particular, notions of software security, computer network security and Web security will be provided, as well as the fundamental principles of cryptography and cryptographic protocols. The main applications in the field of cyber-physical systems, IoT and Cloud/Edge computing infrastructures will also be illustrated.	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Valorisation and dissemination of results, intellectual property and open access to research data and products		6	1	Goals The main objective of the course is to provide the student with fundamental knowledge on the patent system, with a specific focus on the structure of a patent application, on the patentability requirements and their evaluation by examiners, on the main procedures and the different patenting strategies, on how to evaluate possible infringement. The practical	MANDATORY COMPLEMENTARY TRAINING ACTIVITIES (LINGUISTICS, COMPUTER	EVERYONE

				approach and the comparison with experts in the sector will allow participants to develop skills on the protection and valorization of the IP assets. Course contents Introduction to the fundamentals of patent law. Structure of a patent application. Evaluation of patentability requirements (novelty, inventive step, sufficiency of description). Patent procedures and patent filing strategies. University regulations on intellectual property. Representation of a case study.	SCIENCE, MANAGEMENT, ETC..)	

COMPLETE LIST OF 3RD YEAR COURSES WITH DESCRIPTION

Activity/teaching name	SSD	Hours Frontal lesson	CFU	Description	TYPE	CURRICULUM
Innovation and technology transfer	ING-IND/35	6	1	The "Innovation and Technology Transfer" module aims to provide participants with an in-depth understanding of the process of managing innovation and technology transfer in the engineering sector. Goals: The module aims to provide participants with the necessary tools to: ● Understand the process of managing innovation and technology transfer in engineering. ● Analyze the commercial potential of an engineering technology and develop an effective technology transfer strategy. ● Gain knowledge on intellectual property protection techniques and the importance of proper intellectual property management in the technology transfer process. ● Identify the critical factors for successful technology transfer in an international and global environment. Contents: The module is divided into three parts: Innovation Management: This part of the module provides participants with an overview of the key concepts of innovation management in engineering. In particular, the different phases of the innovation process are analyzed, from the initial ideas to the commercialization of the final product. Technology Transfer: The second part focuses on technology transfer. In this section, participants learn about strategies for technology transfer, including licensing, spin-offs, and startup acquisitions. Techniques for assessing the commercial potential of a technology are also discussed. Intellectual Property and International Environment: The third part deals with the issue of intellectual property and the international environment in which technology transfer develops. In particular, the techniques for protecting intellectual property, both at national and international levels, are analyzed. Finally, the challenges and opportunities offered by international markets for the commercialization of technologies are discussed.	MANDATORY COURSE	EVERYONE
Environmental sustainability through product life cycle analysis	ING/IND 15	6		Goals The main objective of the course is to provide the fundamental knowledge to analyze a product from the point of view of its life cycle, evaluate its impacts on the environment and human health, and guide design choices in the direction of sustainability. Course contents Introduction to oriented design. Product life cycle, LCA. Functional unit. Inventory analysis. Impact assessment methods. Allocation of environmental loads. Practical application with	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING

				exercise.		
Experimental techniques and finite element analysis for the industrial sector	ING/IND 14	6		Educational Objectives The course aims to: - provide the ability to choose the most appropriate experimental method to support of the design of biomechanical structures; - provide basic knowledge for the use of numerical calculation codes to support of the design of biomechanical structures; - to acquire appropriate technical language, including the use of terminology scientific in English. Course contents Experimental investigations on metal microlattice structures Finite element analysis of prosthetic devices	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Models and techniques for risk assessment for a sustainable industry	ING-IND/25	6	1	The aim of the course is to provide students with the basic concepts of models and techniques for risk assessment in a sustainability perspective and their integration with enabling technologies. The student will be able to apply the models and techniques to evaluate alternatives and support decisions. - Introduction - Risk analysis models due to equipment deterioration • Statistics of extremes and application for risk analysis • Probability of equipment failure • Numerical exercise - Methods of investigation of surface deterioration • Surface characterization techniques • Laboratory exercise - Use of enabling technologies for risk analysis and management	COURSE OF YOUR CHOICE	INDUSTRIAL ENGINEERING
Modeling uncertainties in building materials and calculating the response of structures	ICAR/08	6	1	The aim of the course is to provide the PhD students with advanced knowledge on the modeling of uncertainties in the characteristics of materials and on the methods for evaluating the structural response in the presence of uncertainties. In practical engineering problems, the properties of materials, the geometry and the boundary conditions of a structure may undergo fluctuations, due to measurement and manufacturing errors, model inaccuracies and/or physical imperfections, which may significantly influence the structural response. In order to describe the uncertainties, reference will be made both to the probabilistic approach according to which the uncertain parameters are represented through random variables with assigned probability density functions and to a non-probabilistic approach developed in the field of interval analysis according to which the uncertain structural parameters are treated as interval variables defined by a lower and upper limit. Furthermore, the tools for evaluating the variability of the response through the methods of random analysis and interval analysis will be provided with reference to recently developed procedures that stand out for accuracy and limited computational burden.	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE
BIM approaches for design and maintenance management of transport infrastructure	ICAR/04	6	1	The course aims to provide the theoretical and operational bases of modern BIM (Building Information Modelling) management systems, with a specific focus on methodological and applicative solutions for transport infrastructures. The aspects related to the characterization of smart objects of the information model of the infrastructure will be studied for applications related to the management of survey data of the quality characteristics of road pavements and for the planning of maintenance interventions.	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE
Sustainability and resilience of urban drainage systems: SUDS	ICAR/02	6	1	The course aims to bring to the attention of participants the most recent intervention strategies for the management of rainwater and wastewater in urban areas as well as the	COURSE OF YOUR CHOICE	CIVIL ENGINEERING AND ARCHITECTURE

				design criteria and types of artifacts suitable for this purpose. Starting from the impact that climate change induces on urban hydraulic systems, the monitoring tools of drainage systems, the technologies for sustainable and resilient urban drainage, the calculation tools to model the various components of drainage systems will be described. Particular importance will be given to the prevention and mitigation of flooding phenomena caused by the increasing waterproofing of the soil and on the solutions aimed at ensuring high levels of hydraulic and environmental protection by addressing the issue of hydraulic invariance and sustainable management of urban rainwater.		
Evolution and Applications of Reconfigurable Digital Systems: From the Apollo Guidance Computer to FPGA Devices	ING/INF01	6		Goals The main objective of the course is to introduce and understand the fundamental concepts underlying the design of modern digital systems based on FPGA. The emphasis will be placed on the possibilities offered by modern technologies and methodologies of design for the development and implementation of complex digital systems with low development costs compared to to ASIC methodologies that are only justified in the presence of extremely high production volumes and are therefore inaccessible to industrial companies with high technological content but of small and medium size. Course contents Digital electronic systems review. Circuits underlying reconfigurable digital systems. Historical perspective of the evolution of reconfigurable digital systems: from PLAs (PALs) to CPLD and FPGA systems. Overview of hardware description languages (HDL) and design methods for implementation on FPGA devices. Examples of implementation of digital systems dedicated to specific applications: timing circuits, control and actuation, circuits for direct digital synthesis.	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Decarbonisation of the electricity system	ING-IND/32	6	1	Educational objectives The aim of the course is to make known and understand the mechanisms of evolution of the electrical system in response to the demands posed by the transition, already underway, towards a sustainable carbon-free energy system and the possible synergies between these mechanisms and the diffusion of electric mobility. Course content The course will deal with the effects that the transition started at national and European level towards a sustainable and carbon-free energy system will have in the coming years on the infrastructures of generation, transport, distribution of electricity and on the methods of final use of energy. In particular, the topics related to the penetration of renewable energy sources in the national electricity system, the diffusion of generation and storage systems distributed throughout the territory and the electrification of final energy consumption will be addressed. The interactions between the evolution of the national electricity system and the diffusion of electric mobility will also be discussed.	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING
Estimation of measurement uncertainty in experimental activities	ING-IND/12	6	1	Objectives The objective of the course is to provide the general rules for the evaluation and expression of measurement uncertainty, with specific reference to the current international regulations. The principles and methodologies illustrated can be applied to a wide range of measurements, including those necessary to maintain quality control and assurance in production or to conduct basic, applied, or development research in science and engineering. Course contents Type A uncertainty. Type B uncertainty. Combined standard uncertainty. Expanded uncertainty and confidence intervals. The Monte Carlo method	COURSE OF YOUR CHOICE	INFORMATION ENGINEERING