Allegato A

Insegnamenti banditi

SSI

Course title	**Nuclear Techniques and Innovative Sensors for Medical Applications**
Scientific Discipline Sector	FIS/01 – FIS/07
Hours of instruction	20 hours
CFU	2
Year	First
Goal	The course introduces basic concepts of nuclear physics applied in medicine, reaching advanced radiotherapies and modern tools of particle simulation studies. The additional goal is to provide a deep understanding of sensor technologies and contribute to the field by developing and implementing innovative dosimetry sensors. Graduates should be capable of conducting cutting-edge research, advancing the field, and addressing challenges in areas such as medical, environmental, and industrial applications of radiation. The program aims to foster critical thinking, research skills, and a strong sense of ethical responsibility in the domain of dosimetry.
Syllabus	• Introduction to the interaction of radiation with matter and dosimetry • Radio isotopes in medical diagnosis • Gamma Camara, Computational tomography basics • PET/SPECT imaging techniques • Innovative radiation therapy with hadrons: HT and BNCT • Monte Carlo on medical physics, Tool for Particle Simulation (TOPAS) • **Introduction to Dosimetry** • **Sensor Technologies** • **Radiation Detection Techniques** • Use of innovative sensors in medical radiation therapy
Bibliography	- Physics in Nuclear Medicine, 4th Edition 2012, Simon R. Cherry, James A. Sorenson, Michael E. Phelps. - Radiation Detection and Measurements, 4th Edition 2010, Glenn F. Knoll. - TOPAS User Guide (http://topas.readthedocs.org/) - Ciofani, G., Genchi, G. G., Liakos, I., & Athanassiou, A. (2018). "Innovative materials for sensors in radiation dosimetry." Journal of Materials Chemistry C, 6(16), 4374-4396. - Attix, F. H. (1986). "Introduction to Radiological Physics and Radiation Dosimetry." John Wiley & Sons.
Examination method	Oral exam by seminary (PP presentation)

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SSI

Course title	**NIR and MIR laser coupling with fibers**
Scientific Discipline Sector	FIS/01 – FIS/03 - FIS/07
Hours of instruction	20
CFU	2
Year	Second
Goal	The goal of the course is to provide students with the basic concepts of how light is guided in optical fibers and how their structure can be optimized to guide near-infrared (NIR) and mid-infrared (MIR) sources.
Syllabus	1. **Step-Index Waveguides:** starting from the scalar Helmholtz equation, hybrid modes HE and EH will be derived in solid core waveguides. 2. **Hollow Core Waveguides:** the propagation of light in void structure will be analyzed, focusing on the several materials employed to realize hollow core waveguides. 3. **Simulation of Solid and Hollow Core Waveguides:** solid and hollow core waveguides will be simulated with COMSOL. 4. **Laboratory activity:** realization of an optical setup for alignment of laser sources with hollow core fibers and measurement of the beam profile of NIR and MIR-coupled sources.
Bibliography	Clifford R. Pollock, Michal Lipson - Integrated Photonics (2003, Springer) Xingcun Colin Tong - Advanced Materials for Integrated Optical Waveguides (2014, Springer)
Examination method	Report on laboratory activity

SSI

Course title	**Real-time Simulation and Hardware-in-the-Loop testing for Smart Energy Systems**
Scientific Discipline Sector	ING-IND/33
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	The course aims to give the fundamentals on the concepts of real-time simulation (RTS) and Hardware-in-the-Loop testing for applications in the fields of smart industry and smart energy systems. The students will also participate to laboratory activities where they will learn to use real-time simulation tools, prepare some basic projects and develop Hardware-in-the-Loop tests on cyber-physical systems. The lab activities will focus on applications for electrical power systems, but applications for any other engineering field can be foreseen (power electronics, mechanical, automotive, etc.).
Syllabus	Digital simulation, Real-time Simulations, Co-simulation, Geographical Distributed Co-Simulation. Classification of real-time simulation testing, Software-in-the-Loop (SIL), Hardware-in-the-Loop (HIL), Control Hardware-in-the-Loop (CHIL), Power Hardware-in-the-Loop (PHIL). Coupling methods, accuracy and stability of simulations. Modelling of an electrical power grid for real-time simulation. Coupling with physical devices. Use of communication network and Standard protocols (i.e Modbus TCP/IP). Seminars on the use of HIL/PHIL in the electrical industry. Prior knowledge of the Matlab/Simulink environment is suggested.
Bibliography	Selected papers and books on the field.
Examination method	The participants will prepare a simple RTS project coherent with their field of expertise using the Simulink-based RT-Lab environment.

SSI

Course title	**Microgrid structures and operation**
Scientific Discipline Sector	ING-IND/33
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	The aim of the course is to describe the methodologies and procedures for planning, managing and controlling multi-energy microgrids, in AC or DC configurations, in grid-connected and islanded modes. Control and supervision of an MG is carried out by a SCADA system that, through proper Energy Management System (EMS), can optimize operation and reliability.
Syllabus	Smart grids and microgrids Planning, management and operation of microgrids in the presence of electric and thermal demand The role of microgrids in markets and enhanced grid integration through ancillary services Design, programming and control of DC microgrid for supplying electric vehicles Experiences on experimental microgrid management and operation.
Bibliography	Scientific papers and books on the selected arguments.
Examination method	A synthetic report on a chosen topic.

SSI

Course title	**Xtended Experiences for Smart and Sustainable Industry**
Scientific Discipline Sector	ING-IND/15
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	Quickly introduce the researchers to the Augmented, Virtual, and Mixed technologies providing the key concepts and methods, and by a hands-on practical laboratory. A course project will be tailored according to researcher's interest. The goal is to explore and envision new and disruptive research domains, applications and experiences.
Syllabus	• Human computer Interface (HCI) history and evolution(4 h, 0.5 CFU): command line, GUI, NUI, Multimodal, Spatial (VR, AR, MR), in-body. Input devices: Physical, Virtual, Voice, Scanners, Gesture, Gaze, Electromyography, BCI. Output Devices: Output: Display, Haptic, 3D audio, Taste, and Smell. • Next-Gen interfaces (4 h, 0.5 CFU): Milgram continuum, AR vs. VR, trends, AR-enabling Technologies, Virtual-Digital combiner (Spatially Augmented Reality, Spatial see-through display, Head-up displays, Handheld Displays, Video see-through HMD, Optical see-through HMD, retinal), AR tracking, AR UI, AR applications, AR metaverse and AR ethics • Kickstart Unity3D (4 h, 0.5 CFU): Why unity, installation with Unityhub, start a new project Interface Layout, Scene-Game workflow, Playmode \ edit mode, How navigate the scene, Create\move basic geometries+ camera, Use of hierarchy, Project Explorer and asset store, Console, Save\retrieve scenes, Deployment. • Project Development (4 h, 0.5 CFU): Conceptualization, implementation, user experience validation, data collection, analysis and report.
Bibliography	• Virtual and Augmented Reality (VR/AR): Foundations and Methods of Extended Realities (XR) 1st ed. 2022 Edition by Ralf Doerner (Editor), Wolfgang Broll (Editor), Paul Grimm (Editor), Bernhard Jung (Editor) • Augmented Reality: Principles and Practice (Usability) 1st Edition by Dieter Schmalstieg (Author), Tobias Hollerer (Author)
Examination method	Course Project and final presentation

SSI

Course title	**Time-series databases for sensor data analysis**
Scientific Discipline Sector	ING-INF/05
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	Despite significant advances in sensor data modeling, most of the space-time data models proposed in the past decade rely on time-stamping of collected data values, simply reusing solutions available in relational databases. The main purpose of the course is to introduce basic notions about modeling time-series information, highlighting the complexity of managing spatiotemporal data and state-of-the-art tools in this field. The course also provides theory, models and methods related to time series analysis detailing the main techniques used to extract value from raw data and to identify new useful information. Predictive analytics approaches, suitable for sensor data analysis, are described and applied to real-world case studies by means of hands-on practical exercises.
Syllabus	• Time-series database: features of time-series data - variability, seasonality, stationarity, autocorrelation; time-series modeling approach - structured data, data stream; basic geospatial data types; time-series DBMS • Processing time-series data: data visualization and monitoring solutions; predictive analytics for sensor data • Using a time-series database: collect data from sensors and systems; query time series data; visualize and manage time series data; processing, analyzing and acting on time series data in real time.
Bibliography	A. Nielsen. Practical Time Series Analysis. O'Reilly Media, Inc. (2019) - ISBN: 9781492041658
Examination method	Online evaluation form composed of 15 multiple choice questions

SSI

Course title	**Physical Layer Security for wireless communication**
Scientific Discipline Sector	ING-INF/02
Hours of instruction	20
CFU	2
Year	First
Goal	The course will address different security techniques based on the physical layer, which are suitable to improve data security in wireless networks and in IoT (Internet of Things) applications. The course participants will gain knowledge of Physical Layer Security techniques. The course will consist of theoretical lectures and numerical hands-on examples.
Syllabus	- Introduction to Physical Layer Security (PLS) and applications - Secrecy notions - Secure array synthesis, beam forming and beam steering - Electromagnetic propagation models in indoor and outdoor environments - PLS keyless approaches - PLS key-based approaches
Bibliography	Scientific papers, slides and support material from the lecturer.
Examination method	Oral or project work

SSI

Course title	**Photonics for Industry 4.0**
Scientific Discipline Sector	ING-INF/02
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	The course focuses on the different photonic technologies that are utilized in advanced manufacturing and high-performance communication within the Smart Industry. Participants will gain knowledge about recent photonic technologies for the Smart Industry and beyond, as well as the use of microcontrollers in creating basic lidar-type devices. The course will comprise theoretical lectures and hands-on workshops conducted in small groups, which will encourage active participation and collaborative problem-solving.
Syllabus	• Introduction to Photonic applications in Industry 4.0 and beyond. • Light Detection and ranging principles and applications. • Light-based manufacturing: Laser additive and subtractive advanced fabrication. Semantic segmentation for automatic feature recognition in additive manufacturing. • Photonics for Automotive. Augmented reality principles. • Introduction to wireless optical communication, free-space optics and light fidelity (LiFi) • Arduino-like microcontrollers for smart industry • Hands-on workshops: practical realisation of a lidar-like prototype device employing Arduino microcontrollers and time-of-flight sensors for smart industry applications
Bibliography	• LiDAR technologies and systems, P. McManamon, SPIE, 2019. • T. Masood and J. Egger, "Augmented Reality: Focusing on Photonics in Industry 4.0," in IEEE Journal of Selected Topics in Quantum Electronics, vol. 27, no. 6, 2021, doi: 10.1109/JSTQE.2021.3093721. • Optical Wireless Communications - An Emerging Technology, M. Uysal, C. Capsoni, Z. Ghassemlooy, A. Boucouvalas, E. Udvary, Springer International Publishing, 2016
Examination method	The exam will consist of a project work, with the completion of a prototype, that enables students in small groups to actively experiment with some aspects of the contents learned during a course.

SSI

Course title	**Nanotechnologies for energy transition**
Scientific Discipline Sector	ING-IND/11
Hours of instruction	20
CFU	2
Year	Second
Goal	This course gives a comprehensive overview of nanotechnology for design engineers working in the energy transition.
Syllabus	This course gives a comprehensive overview of nanotechnology for design engineers. It introduces students to how materials' fundamental physical, electrical, and optical properties change on the nanoscale compared to their bulk counterparts. The methods used to fabricate nanomaterials will be discussed with the physics and chemistry underpinning their extraordinary complexities, empowering students to tailor nanomaterial properties and deduce design principles guiding nanotechnology applications.
Bibliography	Nanotechnology and Nanomaterials for Energy Authors: Pierre Camille Lacaze, Jean-Christophe Lacroix ISBN:9781786304971
Examination method	Written

SSI

Course title	**Energy storage**
Scientific Discipline Sector	ING-IND/08
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	The course addresses the topic of energy storage with a multidisciplinary approach, analyzing the differences between thermal and electrical storage from a global perspective
Syllabus	This course examines different energy storage technologies, empowering the reader to make informed decisions on which system is best suited for their specific needs. Decarbonization is a crucial step towards a sustainable future, and renewable energy plays a vital role in making this transition possible. However, the intermittency of some sources such as wind and solar energy requires the use of energy storage systems. The course contains a detailed study of the fundamental principles of energy storage operation, a mathematical model for real-time state-of-charge analysis, and a technical analysis of the latest research trends, providing a comprehensive guide to energy storage systems. From battery storage systems to hydrogen storage systems, this course provides the tools to effectively manage energy and ensure that excess energy is utilized during times of deficit and signposts the likely future development and lines of research enquiry for each technology discussed.
Bibliography	Energy Storage Systems: Fundamentals, Classification and a Technical Comparative, José Manuel Andújar Márquez, Francisca Segura Manzano, Jesús Rey Luengo
Examination method	Written

SSI

Course title	**Smart energy cities**
Scientific Discipline Sector	ING-IND/11
Hours of instruction	16
CFU	2
Year	Second
Goal	The course addresses the topic of smart cities from the point of view of energy networks.
Syllabus	The focus of this course is on urban and territorial energy infrastructures and the methods that allow their design aimed at their intelligent and automated management, through supervision and control logics aimed at reducing energy consumption, ensuring greater penetration of renewable energies and their greater safety and resilience. The course includes seminars with leading companies in the energy storage sector
Bibliography	Smart Energy in the Smart City: Urban Planning for a Sustainable Future (Green Energy and Technology) Springer ISBN-10:3319809776
Examination method	Written

SSI

Course title	**Microwave Photonics for Smart Systems**
Scientific Discipline Sector	ING-INF/01
Hours of instruction	20 hours
CFU	2
Year	Second
Goal	Microwave photonics is an important interdisciplinary field that, among a host of other benefits, enables engineers to implement new functions in microwave systems. From an educational perspective, the fields of microwave engineering and photonics are often taught in separate courses. This course aims to provide both a theoretical and practical introduction to microwave photonics devices and applications. The first part is on microwave photonics principles and technologies, with a focus on applications and future developments. The second part is a laboratory and aims to prepare students for the final project. It will be shown how to design a simple component, following all the steps from the choice of technological platform to software simulations.
Syllabus	Opening with an overview to the subject, this course covers direct modulation, photonic oscillators for THz signal generation, and terahertz sources. It takes a unique application-focused approach and describes: • Advantages with respect to standard RF technologies; • Basic building blocks; • Design criteria; • Microwave photonic signal processing for Space applications; • Biomedical applications.
Bibliography	Slides provided during the lessons
Examination method	Final project

SSI

Course title	Advanced Fiber Optic Technologies for Biosensing
Scientific Discipline Sector	ING-INF/01
Hours of instruction	20 hours
CFU	2
Year	First
Goal	The goal of this course is to provide a theoretical and simulation-oriented introduction to biosensing with advanced optical fiber technologies. After a brief introduction to the optical fiber's characteristics, the course will focus on a few fiber optic architectures and their working principle for biosensing. This course will also introduce the basic parameters to assess the fiber optic sensors' performance with real-world applications. A few demonstrations of the sensor design will be performed through the simulation tool Comsol Multiphysics and Matlab coding to guide the students for the final project.
Syllabus	1) Introduction to the optical fibers from the Maxwell equations to provide basic concepts including vector and scalar modes. 2) Standard optical fiber materials and working principle of optical fibers for Biosensing. 3) Different fiber optic sensors e.g. photonic crystals, ring resonators and surface plasmon resonance will be introduced with the sensing enhancement principle. 4) The important parameters will be introduced to assess the sensing performance with real world application e.g. protein detection, remote sensing. 5) Few demonstrations will be performed with Comsol and Matlab to provide hands-on experience to the students and prepare them for the final project.
Bibliography	Slides will be provided during the lessons
Examination method	Final project

SSI

Course title	**Fundamentals of Radio Localization and Sensing**
Scientific Discipline Sector	ING-INF/03
Hours of instruction	20 hours
CFU	2
Year	First
Goal	The course is designed to knowledge on various aspects of radio localization and sensing using terrestrial wireless systems, from more traditional scenarios up to the new emerging contexts of 5G and 6G cellular systems.
Syllabus	• Course overview and fundamentals of terrestrial wireless positioning systems: Introduction of the participants and the course; The role of terrestrial radio positioning as a complementary solution to GNSS • Localization approaches based on time and signal strength information in single-input single-output systems: RSS-based methods; TOA-based methods; Hybrid RSS and TOA-based localization • Localization using antenna arrays in sub-6 GHz systems: cooperative schemes and advanced signal processing approaches for dynamic multipath environments: Basics of antenna arrays for positioning; Dynamic Applications • Localization in 5G mmWave multiple-input single-output systems - accurate low-complexity channel estimation and simultaneous localization and mapping: Sub-6GHz vs mmWave; SISO, MISO, SIMO, MIMO Systems; Array architectures; Channel parameter estimation in MISO 5G Systems; Positioning in MISO 5G Systems; Simultaneous localization and mapping in MISO 5G Systems • Joint localization and synchronization using reconfigurable intelligent surfaces in 6G systems: Ingredients of 6G; Going deeper into RIS; RIS for localization and synchronization; Advanced channel models.
Bibliography	- LiDAR technologies and systems, P. McManamon, SPIE, 2019. - T. Masood and J. Egger, "Augmented Reality: Focusing on Photonics in Industry 4.0," IEEE Journal of Selected Topics in Quantum Electronics, vol. 27, no. 6, 2021, doi: 10.1109/JSTQE.2021.3093721. - Optical Wireless Communications - An Emerging Technology, M. Uysal, C. Capsoni, Z. Ghassemlooy, A. Boucouvalas, E. Udvary, Springer International Publishing, 2016
Examination method	Final presentation on selected scientific articles dealing with the topics covered by the course.

DRSATE

Course title	**Cutting-edge Nanomaterials for Advanced Technologies**
Scientific Discipline Sector	CHIM/07
CFU	1
Year	Second
SUMMARY /GOAL	The Cutting-edge Nanomaterials for Advanced Technologies course (1) aims to offer a knowledge base in the field of nanomaterials applied to technologies. The training objective is the understanding of the basic principles and key methodologies in the synthesis, characterization and technological applications of nanostructured materials, to stimulate research in the various emerging sectors of nanotechnology, and also considering the regulatory aspects linked to their use on the environment and human health. Topics overview: • Introduction to Nanochemistry: History and Fundamental Properties. • Synthesis of Nanostructured Materials. • Advanced Characterization of Nanomaterials. • Design and Applications of Nanomaterials for the Environmental Sector, Electronics and Construction Industries, the Textile Sector, and Medicine. • Safety and Regulatory Aspects of Nanomaterials.

DRSATE

Course title	**Materials for the ecological transition**
Scientific Discipline Sector	CHIM/07
CFU	1
Year	First
SUMMARY /GOAL	Contents in summary form: Topic 1: Environmental sustainability, carbon neutrality, circular economy vs. linear economy. Topic 2: Life cycle assessment (LCA) concepts. Topic 3: Materials for sustainable engineering. Topic 4: Sustainable energy production. Reference teaching area: 6. Sustainability and Safety: Materials, Structures, Environment, and Energy.

DRSATE

Course title	**Deep learning applications for Engineering Geology**
Scientific Discipline Sector	GEO/05
CFU	2
Year	First
SUMMARY /GOAL	The course introduces deep learning techniques for Engineering Geology, focusing on recognizing landslide-prone areas and modeling aquifer responses to rainfall. It will use convolutional neural networks to identify landslide areas through geological and geomorphological data and orthophotos, training algorithms to detect and delineate susceptible regions. For aquifer recharge modeling, Multi-Objective Evolutionary Polynomial Regression will formulate responses to rainfall, alongside evolutionary neural networks. Goals: Equip doctoral students with AI knowledge for modeling engineering geology phenomena to prevent environmental risks. Knowledge and Understanding: Students will gain insights into advanced modeling paradigms in environmental geology, enhancing the understanding of complex geological and hydrogeological phenomena beyond traditional methods. Application Skills: Students will apply deep learning and machine learning techniques to comprehend and mitigate environmental risks. Expected Outcomes: Students will become familiar with AI-based data modeling techniques and will be able to implement basic deep learning paradigms using pre-developed tools for geological-environmental modeling

DRSATE

Course title	Lab-and-field data acquisition and analysis for studying Hydraulic Processes
Scientific Discipline Sector	ICAR/01
CFU	2
Year	First
SUMMARY /GOAL	Aim of this course is the introduction to the study of partial differential equations. The three main types of linear second order partial differential equations will be considered: parabolic (diffusion equation), elliptic (Laplace equation), and hyperbolic (wave equation), underling their theoretical and applied features. The course provides the basic concepts necessary to carry out measurements, process data and derive hydrodynamic and physical meanings form large data sets. The following topics are studied, combining theory and practical examples: Measurement definition and concept. Measurement instrumentation and sensors. Sources of error. Measurement uncertainty. Measurement in static and dynamic conditions. Instrument calibration. How to get a calibration curve from laboratory data. Sensitivity, accuracy and precision. Measurement range and frequency response. Instrument precision. Measurement error. Theory of errors. How to carry out a measurement. Nyquist theorem. Sampling duration. Signal analysis in time and frequency domain. FFT and IFFT. How to obtain a spectrum of the measured signal with FFT technique. Acquisition signal chain. Control and management of remote measuring stations, with sensors sampling hydrodynamic parameters. Acoustic and laser signal sources. Doppler effect. Measuring flow velocity with LDA and ADV sensors. Practical trials at the Coastal Engineering Laboratory – LIC of the DICATECh and analysis of acquired data.

DRSATE

Course title	Statistical methods for climate change detection and nonstationary probabilistic modeling
Scientific Discipline Sector	ICAR/02
CFU	2
Year	First
SUMMARY /GOAL	Statistical analysis of environmental variables plays a key role in the process of understanding variability and changes in climate-driven phenomena. The usefulness of this approach is widely recognized in literature, and several tools can be implemented for conduct this kind of analysis. Aim of the course is to illustrate and discuss feasible approaches to probabilistic and statistical methods exploited in this field, providing student basic notions for their implementation in R and Matlab programming languages. The following topics will be covered by proposed course: 1. Introduction to environmental analyses in a changing climate: this introductive part aims to provide a description of key climate variables and their role in interpreting physical phenomena. 2. Notions of probability, statistic and time series analysis: fundamental definitions and axioms of probability and statistic theory; random variables and stochastic processes; statistical characterization of a time series and notes on missing data; references to extreme value theory; 3. Non-stationary processes and statistical test for change-points and trends detection: implications of the presence of deterministic trends in stochastic processes; theory of statistical tests and related errors; power of tests. 4. Elements of R and Matlab and applicative examples: in the last part of the course the utility of Matlab and R programming languages for statistical analysis of real time series will be highlighted. Fundaments of these programs will be illustrated, with the scope to provide main elements for realize a detailed statistical analysis of a time series. Final exam will consist in an applicative exercise in R and/or in Matlab to an environmental time series of the main concepts described during the attendance of the course, with an oral discussion about implemented tools and results.

DRSATE

Course title	**Soil-atmosphere interaction and slope stability: processes and numerical modelling**
Scientific Discipline Sector	ICAR/02 & ICAR/07
CFU	2
Year	Second
SUMMARY /GOAL	Recently the scientific literature has highlighted that climatic factors such as rainfall rate, net solar radiation, relative humidity, wind speed and air temperature determine a set of coupled phenomena, controlling both the skeleton of the soil and the pore fluids in the slope. Such phenomena, on the whole referred to as the 'soil–atmosphere' interaction, can differ in their nature (thermodynamic, hydraulic, mechanical and chemical) and strongly impact the balances of both the liquid and gas masses in the soil pores and the energy balance of the system. The corresponding transient seepage generates – from the ground surface to depth in the slope – variations of the effective stresses and the available shear strengths over time, which in turn impact slope stability. On the whole, the soil–atmosphere interaction at the slope top boundary, together with the processes that it determines in the slope at any depth, represent the 'slope–atmosphere' interaction. Multiple examples of weather-induced deep landslide mechanisms can be found in the Southern Apennines (Italy), which represents a pilot areas where the scientific research is still ongoing. This course will deals with transport processes at the interface between atmosphere and the soil, focussing on the exchange of energy and water between the soil and the lower part of the atmosphere. In particular, different numerical strategies, with different level of coupling, to solve the thermal, hydraulic, and mechanical processes within the soil-vegetation-atmosphere interaction will be presented to simulate and predict water and energy fluxes. Particular reference will be made to risk mitigation, with also the aim to check if such modelling strategies may be of use to design an early warning system to reduce the risk related to landsliding and / or flooding.

DRSATE

Course title	**Mathematical models for transportation systems**
Scientific Discipline Sector	ICAR/05
CFU	1
Year	First
SUMMARY /GOAL	Mathematical models of transportation systems represent, for a real or hypothetical transportation system, the demand flows, the functioning of the physical and organizational elements, the interactions between them, and their effects on the external world. Mathematical models and the methods involved in their application to real, large-scale systems are thus fundamental tools for evaluating and/or designing actions affecting the physical elements and/or organizational components of transportation systems. The goal of this course is to provide the Ph.D. students the theoretical background and knowledge necessary to analyze and manage transportation systems. The course will be focused on mathematical models that represent transportation supply systems (these models combine traffic flow theory and network flow theory models) and transportation demand/supply interactions.

DRSATE

Course title	**Sustainable Mobility and Shared Mobility in a Smart Cities framework: optimization models and applications**
Scientific Discipline Sector	ICAR/05
CFU	1
Year	First
SUMMARY /GOAL	Shared mobility is one of the possible solutions for reducing the traffic congestion problem following the sustainable mobility perspective. It offers the potential to enhance the efficiency, competitiveness, social equity, and quality of life in large cities. The goal of this course is to provide the Ph.D. students the theoretical background and knowledge necessary to manage optimization models for solving shared mobility problems considering environmental aspects. Moreover, basic knowledge in using IBM ILOG CPLEX and MATLAB software for solving Integer Linear Programming models is carried out. The lectures will be structured into two parts. The first part of the course will be focused on the introduction to shared mobility and recent technologies applied to reach the Mobility-as-a-Service concept. Furthermore, a short introduction about optimization models, e.g., Vehicle Routing Problem, for solving transportation issues. The second part of the course will deal with exercises of Integer Linear Programming models through the usage of IBM ILOG CPLEX and MATLAB software.

DRSATE

Course title	**Advances in Geomatic Engineering**
Scientific Discipline Sector	ICAR/06
CFU	2
Year	Second
SUMMARY /GOAL	Recent advances in space (satellite) technology, computing (software and hardware) technology and Geomatic engineering instrumentation technology have had a revolutionary impact on the practice of many engineering fields. The goal of this course is to provide the students the theoretical background and knowledge necessary to manage modern complex geospatial information and technology. The lectures will deal with the following research areas: Multimedia cartography and information delivery; Geospatial Information Science and Geographic Databases; Geospatial Web and Big Data; Technologies and methods in Remote Sensing (proximal/drone/aerial/satellite platforms); Survey and 2D/3D geospatial data processing; Geospatial data modelling and analysis. The advanced topics may serve as an introduction to research skills that may be useful at multidisciplinary level.

DRSATE

Course title	**Advanced Probabilistic Methods For The Reliability Analysis In Structural Engineering Problems**
Scientific Discipline Sector	ICAR/09
CFU	2
Year	Second
SUMMARY /GOAL	Introduction of elements of probability theory applied to structural and earthquake engineering: In the first part, basic elements and references about the common procedures adopted in the structural engineering are provided, accounting, in particular, the case of seismic actions. According to the recent scientific literature, the course will provide an overview about seismic demand quantification, conceptual design, mechanical and geometrical parameters configuration of the buildings, numerical modelling through finite element approaches, linear and nonlinear analyses. Within this framework, the discussion will focus on the basic concepts of probability theory applied to structural engineering, starting from the definition of random variables, statistics and sampling, regression analyses, appropriateness of fit tests, estimation of distribution parameters, testing of hypotheses and related significance. The probabilistic approach of Performance Based Earthquake Engineering (PBEE): In this part, the main limits of deterministic approaches, as commonly used by practitioners, will be highlighted, and the approach of PBEE will be formally presented. Within this framework, all aspects covered by the PBEE will be faced, accounting for the probabilistic study of seismic demand (through the definition of the probabilistic seismic hazard analysis), structural analysis (through the definition of modelling and analysis methods, such as Incremental Dynamic Analysis - IDA, Multi Stripes Analysis and cloud analysis), damage analysis (through the definition of the fragility curves by using articulated and simplified tools) and loss analysis (through the definition of the losses curves by using articulated and simplified tools) (8 hours). Practical examples of PBEE and applications in different fields of civil engineering: Based on the previous concepts, some applications of PBEE to the analysis of Reinforced Concrete (RC) buildings will be shown, with a specific reference to the most useful numerical tools presently available (from the simplest to the most sophisticated).

DRSATE

Course title	**Adaptive Building Technologies for the Mitigation of Local and Global Climate Change**
Scientific Discipline Sector	ICAR/10
CFU	2
Year	First
SUMMARY /GOAL	The aim of the course is to provide students with the knowledge of the effects of climate change and Urban Heat Island (UHI) on built environment. The course will also provide detailed knowledge on the techniques and technologies to adapt the building fabrics to the effects of climate change and UHI and to counterbalance the temperature increase. The first part of the course will explore in detail the major issues of urban climatology, helping in defining the interaction between environmental variables, outdoor surfaces and building fabrics. In the second part of the course detailed students will investigate in detail adaptive technologies to mitigate the temperature effects of climate change-related phenomena. Examples from successful real case studies will be shown. Finally, the third part of the course will provide students with a hands-on experience of modelling techniques and tools to simulate the thermal characteristics of cities and buildings and assess the impact of adaptation technologies. The assessment will be based on the modelling of a selected case study and on the analysis of the effects of different adaptation technologies.

DRSATE

Course title	**Life Cycle Assessment for buildings**
Scientific Discipline Sector	ICAR/11
CFU	1
Year	Second
SUMMARY /GOAL	The aim of the course is to provide students with the knowledge of understanding the impact of the construction sector on the environment, the need for building sustainability, and the regulations driving them. Then the students will learn about the core concepts of LCA, including building life-cycle stages and environmental impact assessment. Finally, the third part of the course will provide students with a hands-on experience of modelling techniques and tools to simulate a LCA of a case study building. The assessment will be based on the modelling of a selected case study and on the analysis of the effects of different adaptation technologies.

DRSATE

Course title	**Research in Architecture and Engineering Aided by Information Models: From BIM to Digital Twin for the Built Environment**
Scientific Discipline Sector	ICAR/11
CFU	1
Year	First
SUMMARY /GOAL	In architecture, engineering and construction (AEC) research, information modelling methods and technologies have been further investigated to enhance design, assessment, execution and management of the built environment. Among these methods, Building Information Modelling (BIM) research is still evolving from data collection, information integration and knowledge management for new buildings and assets. The approach has also been developed for refurbishment / restoration of historic buildings and tangible Cultural Heritage, turning it into HBIM (Heritage or Historic BIM). In both the research directions, BIM is recently used to create the parametric virtual twin of the real entity to support the creation of the Digital Twin Framework, able to support decisions before the project stage through simulations, and during operation and maintenance activities through monitoring and analysing performance data. This course will provide theoretical and practical reference about current and future research about and with BIM methodology and tools, underling potential research in different construction engineering domains. Fundamentals in data structure and data types will be provided aiming at interoperable pipelines with further Information Systems, according to different application domains.

DRSATE

Course title	Analysis and representation techniques for building research
Scientific Discipline Sector	ICAR/17
CFU	1
Year	First
SUMMARY /GOAL	The course introduces the theoretical and practical knowledge necessary for conducting three-dimensional surveys of built structures (buildings, infrastructures, monuments, urban systems, and cities) and the territory using the most modern digital photogrammetric techniques. The following topics will be covered by proposed course: - Introduction to digital surveying with a focus on aerial and terrestrial photogrammetry. - Overview of basic mathematical tools for stereoscopic restitution and potential errors. Coordinate systems used in photogrammetry. - Notes on photographic techniques and color theory. Digital images: acquisition and geometric and radiometric characteristics, image processing and analysis techniques. - Camera orientation procedures. - Introduction to terrestrial laser scanning, a complementary technique to photogrammetry for creating 3D surveys in construction, architectural, and industrial contexts. - Survey campaign design for buildings with simple and complex geometry. - Reconstruction of 3D surface models. - Visualization and management of point clouds and generation of meshes, textures, and derived products. - Possibilities for integrating digital photogrammetry with other techniques. - Photogrammetry applications to real case studies.

DRSATE

Course title	Laser scanning for architectural surveying. Techniques and applications
Scientific Discipline Sector	ICAR/17
CFU	1
Year	Second
SUMMARY /GOAL	This course provides a comprehensive overview of modern architectural surveying techniques, with emphasis on laser scanning and point cloud management. The goal is to transfer practical skills and knowledge applicable to real projects in the field of architectural heritage. Initially, the lecture covers the fundamentals of architectural surveying, comparing traditional methods with digital advances. Then, laser scanning, details of LiDAR technology, photogrammetry, and various applications in engineering, architecture, cultural heritage, reverse engineering, and public safety are explored. The different types of laser scanners and their principles of operation, particularly phase-shift scanners, are examined. The course also delves into point clouds, discussing their basic concepts, creation with laser equipment, and alignment using Autodesk Recap software. Data processing techniques such as filtering, decimation and AI segmentation are covered. The program concludes with an interactive final project in which participants plan and conduct a laser survey, acquire and process data, and extract architectural elements. This hands-on component reinforces the practical application of the skills learned.

DRSATE

Course title	Complex Knowledge Management and Intelligent Systems for Territorial Engineering
Scientific Discipline Sector	ICAR/20
CFU	1
Year	First
SUMMARY /GOAL	The course aims to provide theoretical foundations and practical tools necessary for the utilization of advanced methods in constructing digital twins and computational models increasingly prevalent in the field of engineering in general, particularly in current territorial engineering and urban planning contexts. The theoretical presentation of methodologies and hands-on experience with innovative digital tools will be complemented by reflections on emerging scenarios in both research and practice within engineering domains, driven by new technologies (big data, grid and cloud computing, iaas, paas, and saas services). This aims to enrich students' cultural background with new project development possibilities, from conceptualization to practical and detailed realization. The course will consist of two parts: theoretical and practical.

DRSATE

Course title	How to build an ontology that lasts for design matters: Theory.
Scientific Discipline Sector	ICAR/20
CFU	2
Year	First
SUMMARY /GOAL	'Applied Ontology' is an approach developed within Artificial Intelligence and aimed to build symbolic representations of (a fragment of) reality. The use of applied ontology ensures that the result is conceptually coherent, semantically clear and computationally robust. In this course we introduce the motivations and methodology of applied ontology focusing on (a) the distinction between data and information; (b) the DOLCE ontology; (c) the conceptual analysis of simple scenarios of urban and social interest; (d) methodologies for ontology-based model construction; and (e) the use of software (e.g., Protege) for ontology construction.

DRSATE

Course title	How to build an ontology that lasts for design matters: Lab.
Scientific Discipline Sector	ICAR/20
CFU	1
Year	Second
SUMMARY /GOAL	The course aims to develop models to build ontological representations of knowledge, applied in particular to Town and Country Planning (Planificazione urbanistica e territoriale) and Territory Engineering (Ingegneria del territorio). Lessons learned from recent Poliba research, such as the monastery as an architectonical type and urban square as a physical and social place, will be retrieved and discussed. As a whole, the program is focused on: (i) a brief introduction recalling basic aspects of theory; (ii) examples and exercises for application to each studied disciplines, particularly to Town and Country Planning and Territory Engineering. In this lab course each student will be asked to develop a work concerning the application of theoretical topics to a specific case, which can be identified at their choice among the topics of their doctoral course.

DRSATE

Course title	**Sustainable Technologies for Circular Economy in Waste Management**
Scientific Discipline Sector	ING-IND/22
CFU	2
Year	Second
SUMMARY /GOAL	Today's linear economic model (take-make-dispose) is wasteful and unsustainable. In a circular economy, the maximum value is extracted from resources in use, then products and materials are recovered and regenerated at the end of each service life. The transition from a linear economy to a circular economy is currently one of the biggest challenges in the field of waste management. In this perspective, the aim of this course is to develop scientific and technical aspects on the closing the loop of both urban and industrial waste. The goal is to ensure PhD students obtain a solid background in environmental technologies, with competencies for designing and tailoring new waste management systems, and with a specific view to the sustainability of processes and technologies. The course is developed on principles of Circular Economy and Sustainable Development, on circularity as a tool for saving non-renewable raw materials and reducing the waste production. In particular, the lessons discuss basic scientific principles and recent technological advances in current strategies for resource recovery from waste (for example: recycling of dry waste and composting of organic waste). Also, the course presents solutions to pressing problems associated with waste management and treatment, as well as the health impacts created by improper waste disposal and pollution. The major topics covered by the course are: 1) circular economy and sustainability: basics and application; 2) closing the loop: the circularity as a tool for saving raw material and natural resources and to reduce waste production; 3) industrial symbiosis and urban mining definition; 4) recovery and recycling of industrial and urban waste; 5) innovative and sustainable technologies: pre-treatment and selection, mechanical-biological treatment, energy recovery, disposal in landfills; 6) use of secondary raw materials.

DRSATE

Course title	**Multiscale models for material science**
Scientific Discipline Sector	MAT/07
CFU	2
Year	First
SUMMARY /GOAL	Elements of Statistical Mechanics Thermo-mechanical methods for multistable materials Single-molecule models Rate effects Network models

DRISS

Course title	Numerical and experimental modelling of heat transfer
Scientific Discipline Sector	ING-IND/08 – ING-IND/10
CFU	2 (Modulo A: 1 ING-IND/08 + Modulo B: 1 ING-IND10)
Year	First
SUMMARY /GOAL	This SCUDO course will deepen the fundamentals of thermofluidic systems with emphasis on their application in thermal engineering system, addressing advanced topics in applied thermodynamics, fluid mechanics, and heat transfer. The course provides a detailed presentation of selected advanced topics in thermophysical systems to solve related engineering problems, including principles of complex fluid flows, innovative modelling and multi-dimensional techniques. Focusing on engineering applications, students will be able to handle practically the problems of thermal engineering and energy conversion systems. Efforts will be made to introduce students to relevant advanced technologies in applied thermal engineering and renewable energy systems such as the thermal energy storage systems (TESS), heat exchangers, PV-T systems, phase change materials (PCMs), and nanofluids. Problems and examples include theory and applications drawn from a spectrum of engineering design and manufacturing problems.

DRISS

Course title	Construction safety: legal and administrative aspects, technical standards
Scientific Discipline Sector	ICAR/08 – IUS/17
CFU	3 (Modulo A: STRUCTURAL ENGINEERING 1 ICAR/08, + Modulo B : TECHNICAL STANDARDS 1 cfu ICAR/08 + Modulo C : LEGAL ASPECTS 1 IUS/17)
Year	First
SUMMARY /GOAL	Nowadays, the structural safety of constructions is a key problem, especially for critical infrastructures like bridges, industrial and energy production plants, etc.. Indeed, eventual collapses may involve risks not only for human lives but also for the preservation of the environment. This course proposes a multidisciplinary approach for giving effective answers to the safety of construction problems, involving different points of view, coming from the fields of structural engineering, technical standards, and legal aspects.

DRISS

Course title	Innovative devices for seismic risk protection
Scientific Discipline Sector	ICAR/09
CFU	2
Year	First
SUMMARY /GOAL	This course will introduce the use of innovative devices for seismic risk protection of Reinforced Concrete (RC) structure. In particular, the retrofitting of the latter will made using hybrid technological systems based on laminated timber panels. The main goals will be the evaluation of the structure's response and the consequent reduction of seismic risk.

DRISS

Course title	Energy Production: Storage, Emerging Technologies & Social Challenges
Scientific Discipline Sector	ING-IND/10 – ING-IND/35
CFU	2 (Modulo A: 1 ING-IND/10 + Modulo B: 1 ING-IND/35)
Year	First
SUMMARY / GOAL	This SCUDO course will deepen the fundamentals of distributed energy production and distribution of energy. The course aims to provide PhD students with methodologies to support a renewable energy transition for renewable energy communities (REC) looking at investigated in three different modules, emerging technologies for energy production (1), the energy storage opportunities and technologies (2) and social aspects behind the implementation of practices of (REC). The course will provide the tools to carry out an evaluation of the use of energy resources, making the PhD students aware of the methodologies for carrying out an energy production and management systems. The course therefore aims to provide specific technical knowledge on the application and use of the main renewable energy sources, encouraging critical development towards a path aimed at the efficient use of energy resources. During the course, through case studies, the ability to propose both managerial and technological-system interventions will be developed, and advanced tools for visualizing energy consumption will be presented, facilitating its monitoring.

DRISS

Course title	Mechanical models for masonry structures
Scientific Discipline Sector	ICAR/08
CFU	2
Year	Second
SUMMARY /GOAL	Although masonry constructions represent the vast majority of the architectural heritage, to date the scientific community is still wondering about the definition of the most appropriate structural models, especially for the analysis of complex structures (arches, vaults, domes) and for the study of the effects of seismic actions. This course will offer to the Ph.D. students a state-of-the-art review of mechanical models for masonry structures, also giving suggestions for new research directions to be followed.

DRISS

Course title	Seismic risk of reinforced concrete buildings: innovative modeling, analysis, and mitigation strategies
Scientific Discipline Sector	ICAR/09
CFU	2
Year	Second
SUMMARY /GOAL	This course aims to investigate the reinforced concrete response of some cases study. The structural response of reinforced concrete buildings will predict through Machine Learning applications. In particular, Matlab algorithms and Straus software will be used and discussed in this course. This approach will be discussed.

DRISS

Course title	Dynamic identification and structural monitoring: fundamentals and applications to wind turbines
Scientific Discipline Sector	ICAR/08 – ICAR/09
CFU	2 (Modulo A: 1 ICAR/08 + Modulo B: 1 ICAR/09)
Year	Second
SUMMARY /GOAL	This course concerns experimental investigations of the structural response of wind turbines, in order to calibrate models for structural analysis under dynamic loads, like wind and seismic actions, and to investigate the structural health of those structures. Applicative issues will be introduced by theoretical and experimental fundamentals.

DRISS

Course title	Bridges and critical infrastructures: seismic risk and wind-structure interaction
Scientific Discipline Sector	ICAR/09
CFU	2
Year	Second
SUMMARY /GOAL	This course aims to investigate the structural response of bridges and high-rise buildings under the simultaneous action of wind flow and seismic impulse. The main goal is to estimate the multi-hazard effects on flexible structures, the seismic and wind actions. The calculation of the induced vibration and the comfort limits for users and occupants will be discussed.

DRISS

Course title	Characterization and modeling of light alloys
Scientific Discipline Sector	ING-IND/16
CFU	2
Year	Second
SUMMARY /GOAL	This course will be focused on the main experimental methodologies for the technological characterization of light alloys for automotive/aerospace/biomedical applications.

DRISS

Course title	Numerical and heat transfer challenges in Thermal Energy storage
Scientific Discipline Sector	ING-IND/08 – ING-IND/11
CFU	2 (Modulo A: 1 ING-IND08 + Modulo B: 1 ING-IND/11)
Year	Second
SUMMARY /GOAL	The course addresses the topic of energy storage with a multidisciplinary approach, analyzing the differences between thermal and electrical storage from a global perspective. This course examines different energy storage technologies, empowering the reader to make informed decisions on which system is best suited for their specific needs. Decarbonization is a crucial step towards a sustainable future, and renewable energy plays a vital role in making this transition possible. However, the intermittency of some sources such as wind and solar energy requires the use of energy storage systems. The course contains a detailed study of the fundamental principles of energy storage operation, a mathematical model for real-time state-of-charge analysis, and a technical analysis of the latest research trends, providing a comprehensive guide to energy storage systems. From battery storage systems to hydrogen storage systems, this course provides the tools to effectively manage energy and ensure that excess energy is utilized during times of deficit and signposts the likely future development and lines of research enquiry for each technology discussed.

DRISS

Course title	Smart buildings
Scientific Discipline Sector	ING-IND/11
CFU	2
Year	Second
SUMMARY /GOAL	Smart zero energy buildings combine energy efficiency measures and renewable energy generation to consume only as much energy as can be produced onsite through renewable resources over a specified time period. This course aims to discuss how to address the energy issues in net-zero energy buildings (ZEB), using multicarrier energy systems with hydro-wind-solar-hydrogen-methane-carbon dioxide-thermal energies. The course aims to present approaches and solutions to make possible the evolution of the building sector away from a carbon-based (*and GHG-intensive*) approach. Multiple solutions will be investigated from traditional renewable hydro-wind-solar energy sources to new technologies such as fully-electrical systems or hydrogen-based systems. The course aims to present solutions for minimizing the released CO_2 to the atmosphere due to buildings and in doing this, it will teach approaches to increase the energy resilience within the built environment. At the end of this course, students will be able to: 1. Assess the energy demand of buildings and to discuss strategies to achieve net-zero targets with smart energy management 2. Design multi-source smart renewable energy resources for buildings and carry out the design of multiple building renewable energy systems, including photovoltaics and solar thermal systems. 3. Calculate the carbon and energy balance of building HVAC systems and compare them within a life cycle approach 4. Calculate the emission factors of different energy systems and their respective trade offs

DRISS

Course title	Indoor comfort evaluation
Scientific Discipline Sector	ING-IND/11
CFU	2
Year	Second
SUMMARY /GOAL	The course will provide an introduction to the basic principles of indoor environment quality including thermal, visual, acoustic comfort as well as indoor air quality. After a brief introduction on the subjective/physiological parameters and their objective counterparts, a quick tutorial on measurement techniques will be provided.

DRISS

Course title	Analysis and management of heritage buildings: efficiency and innovative technologies
Scientific Discipline Sector	ICAR/10 – ICAR/12
CFU	2 (Modulo A: 1 ICAR/10 + Modulo B: 1 ICAR/12)
Year	Second
SUMMARY /GOAL	This course will explore the concepts of efficiency in historic buildings, highlighting the role of innovative technologies in improving building performance from building decarbonization perspective. Furthermore the module provides a general overview of the methodological workflow supporting the assessment and control of performances, risk vulnerabilities and pathologies in traditional and modern heritage buildings, with specific focus toward onsite non-destructive survey, diagnostics and monitoring techniques, as well as emerging solutions for data processing and management. In detail, theoretical contents, experimental applications and international research experiences and studies will address the following specific topics: ▪ The diagnostic process: conceptual, operational and normative framework; ▪ Onsite investigation of masonry, reinforced concrete and timber building components: methods, techniques and operation protocols; ▪ Digital 2D/3D reality-based models for decay mapping and monitoring, multi-spectral imaging and multi-sensory data collection: research trends and relevant application. Collaborative virtual platforms for data collection, analysis and management: WebGIS, BIM, VR/AR.

DRISS

Course title	Resilient and secure (historic) built environment in a multi-hazard perspective
Scientific Discipline Sector	ICAR/10
CFU	2
Year	Second
SUMMARY /GOAL	The course will focus on a general overview of theories about risk assessment in single and multi-risk scenarios – both synchronous and asynchronous – in order to provide a practical toolkit to PhD students for understanding and analyzing the multi-vulnerabilities of the historic built environment (e.g., urban historic districts). Starting from the study of international normative and scientific background, the module will provide: ▪ Introduction on the meaning of risk and its assessment for the built environment, coherently with the theories of the "secure and resilient cities"; ▪ Operative methods to study the occurrence of natural and anthropic hazards (e.g., phenomenological analysis of historical events or onsite measurements); ▪ Strategies and tools for the study of combinations of actions or effects in multi-risk scenarios. ▪ Digitalization of knowledge for the risk communication of the built environment (GIS-based, VR-based) towards decision-supporting systems.

DAUSY

Course title	Distributed/Decentralized Control and Optimization of Large-Scale Systems
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	This course aims at providing PhD students with modeling and methodological tools for formulating and solving large-scale optimization problems with a focus on the use of duality theory. During the course several optimization problems will be formalized, particularly referred to relevant issues within management and industrial engineering. Problem definition and resolution will be also implemented in simulation and engineering software (Matlab). The final goal is to provide PhD students with the necessary background for starting research in the field of duality-based decentralized and distributed optimization techniques to be applied to large-scale systems. Each lesson consists in lectures, numerical examples, simulation and analysis of case studies.

DAUSY

Course title	Non-integer order systems and controllers
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	The course concerns non-integer-order systems. These systems can propose engineering solutions to modeling and control problems that often improve those based on integer-order calculus. Basic tools of fractional calculus are introduced, and some methods and models are described for different engineering fields. Models for practical applications are proposed. Moreover, approaches to design and realize non-integer-order (fractional-order) controllers are described. These controllers show higher flexibility, increased robustness, and ability to obtain a better trade-off between stability and dynamic performance with respect to widespread PID controllers. As case-studies, the course uses applications in automotive and mechatronic systems.

DAUSY

Course title	Deep Reinforcement Learning for Control of Autonomous Systems
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	First
SUMMARY /GOAL	Reinforcement learning deals with solving sequential decision problems when minima prior information is available. Solving sequential decision problems means finding their optimal control policies. Using reinforcement learning algorithms, the optimal policy is learned through the cooperation between the agent (or controller) and the system to be controlled. Deep Reinforcement Learning (DRL) is a subfield of machine learning that combines reinforcement learning (RL) and deep learning. The course will propose the main modeling frameworks, investigate the most relevant deep reinforcement learning techniques and show some interesting applications.

DAUSY

Course title	Control and Security of Cyber Physical Systems
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	The aim of the course is to show the importance of control and security in Cyber Physical Systems (CPSs). CPSs are systems where a decision making(cyber/control)component is tightly integrated with a physical system(with sensing/actuation) to enable real-time monitoring and control. Therefore, control and security are crucial issues for commissioning these systems and for improving competitiveness of companies. In this context, the study of opacity is a fundamental notion to determine if an industrial "secret" can be discovered by a malicious observer (intruder).

DAUSY

Course title	Simulation Systems for Engineering Applications
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	First
SUMMARY /GOAL	The course shall address the basis of simulation techniques for engineering applications, with a focus on the underlying mathematical formalism. At end of this course students will be able to deal with system modeling and to implement simulation models in engineering tools (e.g., Python, Matlab). Each lesson shall consist in lecture and numerical examples.

DAUSY

Course title	Simulation, optimization, and management of smart energy systems
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	First
SUMMARY /GOAL	The course will focus on models, techniques and tools for the simulation and optimization of energy systems in smart buildings and smart mobility applications. At the end of this course students will achieve the basics for modeling and simulating such energy systems using engineering tools (e.g., Matlab, SUMO). Each lesson will consist in lecture and software exercises.

DAUSY

Course title	Game Theory for Controlling Autonomous Systems
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	This course is designed to provide PhD students with the necessary modeling and methodological tools for analyzing and designing algorithms to solve game equilibrium problems. The course will include lectures, numerical examples, simulations, and analysis of case studies.

DAUSY

Course title	Modeling and simulation of biosystems
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	First
SUMMARY /GOAL	This course provides mathematical tools to model, analyze, simulate and control biological and medical systems, exploiting both deterministic and stochastic frameworks. At end of this course, the students will be able to deal with system modeling and to implement simulation models in Matlab.

DAUSY

Course title	Dynamical stochastic models of biological systems
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	First
SUMMARY /GOAL	This course gives the mathematical tools to model and analyze most common biological frameworks such as chemical reactions and gene transcription networks, according to the stochastic approach of the Chemical Master Equations.

DAUSY

Course title	Data-driven fault diagnosis and fault prognosis
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	This module aims at providing PhD students with the main concepts of data-driven fault diagnosis and fault prognosis which are at the base of modern condition-based and predictive maintenance. During the module, the students will learn how to apply a data-driven workflow to solve real case studies and to adapt it to the specific cases of fault diagnosis and fault prognosis. The workflow will include data processing, feature extraction and model training, with some insights on deployment complexity; problem resolution will also be implemented by using a common engineering software (MATLAB). The final goal is to provide PhD students with the necessary background to process sensors data and use them to monitor the condition of a physical system, classify possible undesired behaviours and eventually estimate the remaining useful life of specific components. Each lesson consists in lectures, numerical examples and analysis of case studies.

DAUSY

Course title	Gaussian processes for modeling and control of robotics systems
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY /GOAL	The course shall address the basis of Gaussian Process Regression applied to modeling and control of robotic manipulators. At end of this course, students will be able to apply Gaussian Process Regression to the following problems: ▪ Inverse dynamics identification; ▪ Estimation of forward dynamics model to simulate the evolution of a robotic system; ▪ Use such models to derive a controller. Lesson shall consist in lecture and numerical examples in MATLAB and Python.

DAUSY

Course title	Human autonomous system interaction
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	The course aims at providing PhD students with the main concepts of the well-known technology for improving human-autonomy interaction with a special focus on autonomous systems. It is especially focused on technology and case studies relevant to complex, applied environments in which people interact with autonomous systems regularly, particularly in the context of ambient assisted living. The course focuses on approaches that include task inputs from humans: how to model humans and their tasks and at what level of details. Moreover, the human in-the loop approach will be introduced as a new scenario to facilitate the goal achievement, to reduce the anomalies and the unexpected responses from the system or inappropriate responses by the human to enhance human safety. New human-system engineering techniques are needed to ensure autonomous systems will be smoothly and readily adopted into society. Autonomous systems that work together in the environment should integrate the connections and interactions between them, over networks, with the physical environment, and with humans must be assured, resilient, productive, and fair in the autonomous future. Autonomous systems should be analysed including concept, context, requirements, design, integration, operationalization, validation, testing and evaluation. During the course, the students will learn how the human-autonomous system interaction is achieved and how it is articulated. The workflow will include data processing, feature extraction and model training for human-robot interaction tasks, with some insights on deployment complexity; problem resolution will also be proposed by using a common engineering software (MATLAB), and the ROS (Robot Operating System). Each lesson consists in lectures, numerical examples and analysis of case studies.

DAUSY

Course title	Intelligent Supervisory Systems
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY /GOAL	This course aims to offer a foundation of intelligent supervisory system techniques and their application in various real-world domains and how to implement a solution with “intelligent” functionality. Students will learn to judge when intelligent functionality and artificial intelligence may be a good solution for a problem and be able to choose suitable artificial intelligence methods and techniques. Students will also acquire knowledge enabling them to develop the necessary skills to design and implement an intelligent supervisory system.

DAUSY

Course title	Introduction to autonomous systems
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	The course aims at providing PhD students with the fundamental principles, technologies, and applications related to autonomous systems.

DAUSY

Course title	Linear algebra for control applications
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY /GOAL	The course will introduce advanced linear algebra tools that are commonly used in many applications in Control and System Theory. The course will address this topic from different perspective: 1. Theory with formal proofs of many results, 2. Algorithms to understand the most common algorithms used in MATLAB or Python for linear algebra, 3. Implementation via MATLAB of algorithms and performance evaluation on large data sets.

DAUSY

Course title	Linear and nonlinear Kalman filtering: theory and applications
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY /GOAL	This course aims to provide both theoretical and practical tools to tackle estimation problems encountered in several areas of engineering and science. In particular, it is shown how to formulate such estimation problems as instances of a general dynamical system state estimation problem and how to derive the mathematical solution of the latter problem. Then it is shown that, for a linear Gaussian system, such a solution yields the well known Kalman filter. Further, approximate techniques (e.g. extended and unscented Kalman filters, particle filter, etc.) are presented for the case of nonlinear and/or non-Gaussian systems, for which an exact closed-form solution cannot be found. To conclude the theoretical part, theoretical limitations (i.e. the Cramer-Rao lower bound) on the quality of estimation are discussed. In the final part of the course, we illustrate some applications of linear/nonlinear Kalman filtering (e.g., tracking, robotic navigation, environmental data assimilation).

DAUSY

Course title	Optimal control for Climate change and air quality
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	First
SUMMARY /GOAL	The course will address the fundamentals of the modelling and control of real-world systems, presenting the application of control theory to climate change and air quality. Each lesson shall consist in lecture and numerical examples.

DAUSY

Course title	Learning in multi-agent systems
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to provide a thorough overview of learning and optimization in multi-agent systems. At the end of the course, students will be familiar with applications, with the challenges of decentralized learning, and the current state-of-the-art solutions. Additionally, they will have an overview of current research trends and opportunities. Lessons will merge theoretical lectures and numerical examples (using Python).

DAUSY

Course title	Non-linear Control
Scientific Discipline Sector	ING-INF/04
CFU	2
Year	Second
SUMMARY /GOAL	The course introduces analytical tools for the analysis and design of nonlinear control systems. At the end of the course students will understand how to analyze the stability of nonlinear dynamic systems and knowledge of some of the main approaches for designing nonlinear controllers. Basic engineering examples and Matlab exercises are provided.

DAUSY

Course title	Variable Structure Control
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	Second
SUMMARY /GOAL	Variable Structure Control (VSC) is a control technique who force a dynamical system to behave as a Variable Structure System (VSS) whose characteristics satisfy the required performance, in spite of a class of uncertainties in the system dynamics and external disturbances. In particular the system is forced to reach and remain constrained onto a properly chosen surface of the state space such that the movement on such a surface, i.e., the Sliding Mode (SM), is invariant and corresponds to specifications. The lectures will present the general theoretic and applicative framework of VSC with SMs, presenting it in the more general vision of the control systems. Some of the mathematical tools to analyze and design a VSC with SM will be presented and discussed, also by means of simple examples. The limits of the resulting switching control, the tools to analyze the approximate behavior and the approaches to mitigate the so-called chattering phenomenon will be presented and discussed. Finally, some applications of VSC to real systems and to observer design will be presented.

DRIG

Course title	A user- centered approach to Ergonomics assessment in the Industry 5.0 paradigm
Scientific Discipline Sector	ING-IND/15
CFU	2
Year	First
SUMMARY /GOAL	The Industry 4.0 program and the perspectives of the innovative I5.0 approach are significantly changing the role played by the operator on the smart factory shopfloor. The introduction of the mass-customization paradigm and the fast changes in the production cycle require new operators' capabilities. In particular, the I4.0 operator is requested to be a smart element in the production cycle, able to adapt to sudden changes by means of decisional capabilities. In order to strengthen such capabilities, it is necessary to optimize the working conditions so as to free operators from unnecessary tasks and allow them to use their physical and cognitive resources in an optimal manner. The Human Performance Envelope (HPE) constitutes the set of factors that define the conditions in which the operator acts and encompasses environmental, social, physical, and cognitive aspects. In order to optimize the operator's performance, it is essential to understand the processes that govern the definition of the HPE, thus allowing both designing efficient solutions and applying rigorous validation procedures. Thanks to technological innovations (e.g. low-cost tracking systems and physiological signals platforms), nowadays it is possible to apply an integrated approach for the HPE assessment using both traditional and novel methods. The course will be composed of 3 modules aiming at providing Ph.D. students with the necessary knowledge to validate in their scientific research the effectiveness of solutions designed in order to improve the operator's performance with particular attention to the HPE. Module I. Introduction and theoretical bases. The role of the Operator in the I4.0 smart factory. Introduction to the concept of HPE and its fundamental components —the physical and the cognitive workload. Basic principles of the Cognitive Load Theory. The ISO standard 11226 Ergonomics — Evaluation of static working postures. Module II. Assessment methods for physical ergonomics. Post-hoc measures (the Borg-CR 10 scale), direct methods, observational methods (the Rapid Upper Limb Assessment metrics), and innovative applications for the observational methods (the ErgoSentinel tool). Module III. Assessment tools for cognitive ergonomics. Post-hoc measures (the NASA Task Load Index, the Multiple Resource Questionnaire), task performance measures (Completion time, Error Rate, reaction Time, the dual-task design); direct methods (the electrocardiographic signal and the Heart Rate Variability Analysis approach). By the end of the course, Ph.D. students will have a broadened knowledge in the field of the Industry 4.0 paradigm through the awareness of the new role of the operator and the knowledge of the HPE concept. Furthermore, they will be able to handle tools for physical and cognitive workload assessment and for designing an experimental setup in order to validate innovative solutions for HPE improvement.

DRIG

Course title	Metaverse Integration for Digital Transformation of industry
Scientific Discipline Sector	ING-IND/15
CFU	2
Year	First
SUMMARY /GOAL	This course provides an in-depth exploration of the metaverse as a fundamental catalyst for digital transformation in an increasingly evolving industrial context. Balancing theory and practice, participants are guided through a series of modules designed to provide a comprehensive and applied understanding of key concepts. The introduction will outline the fundamental importance of the Metaverse in the context of the Digital Transition. The first module will explore the history and development of metaverse technologies. A clear distinction will be made between virtual reality, augmented reality and the metaverse concept itself. The second module, through the study of successful cases and the analysis of successful implementation strategies, will explore the practical applications of the metaverse in a business context. The third module will provide an overview of enabling technologies. It will examine how Artificial Intelligence and Blockchain can empower the Metaverse and accelerate the digital transition. The fourth module is highly practical. It will guide participants in designing immersive experiences and developing a strategic plan for integrating the metaverse into the corporate environment. Hands-on experience will be provided through practical sessions using virtual reality metaverse development platforms such as the Unity game engine. The course conclusions will summarise the acquired knowledge and prepare the participants for the final project. The aim of this assignment is to develop a practical project that applies the concepts of Digital Transition through the metaverse. After completing the course, the theoretical and practical learning will be reinforced by presenting and evaluating projects. The course aims to train participants as informed Digital Transition leaders, equipped with the skills to fully exploit the potential of the Metaverse in the business domain, through theoretical lectures and practical sessions.

DRIG

Course title	Basic concepts on elliptic equations
Scientific Discipline Sector	MAT/05
CFU	2
Year	First
SUMMARY /GOAL	The aim of the course is to present some basic aspects for elliptic equations and to show how solutions of this type of equations can be obtained through optimization of suitable functionals

DRIG

Course title	Mathematical methods in deep learning
Scientific Discipline Sector	MAT/05
CFU	2
Year	First
SUMMARY /GOAL	This course, intended for Engineering Ph.D. Students, has the objective to provide the basic mathematical concepts needed to have a clear insight of the mechanism of neural networks in deep learning. This will help engineers in exploiting neural networks as a tool in a conscious way. The theory treated in the course is the following. 1) We will start by introducing the basic architecture of a feedforward neural network defined basing on weights. For this, we shall recall some basic facts in tensor algebra. 2) We will explain some examples of Universal Approximation Theorems, highlighting the ideas behind the fact that a neural network is capable to approximate any continuous function. 3) We will introduce the concept of cost in a feedforward neural network, providing some examples of nonlinear costs. Among these, we will put some stress on the cross-entropy cost, recalling some basic facts in statistics about maximum likelihood estimation. 4) We will introduce some numerical methods for nonlinear optimization: the gradient descent, stochastic gradient descent, momentum update. 5) We will explain how all the previous ingredients are combined together in the feedforward-backpropagation algorithm used for data-driven learning. In parallel with the theory, we will illustrate how to implement it using the PyTorch library in some educational examples in image recognition and language models, putting some stress on the process of babysitting a neural network (initialization, normalization, checking overfitting). Projects proposed by the Ph.D. Students will be strongly encouraged.

DRIG

Course title	Advanced Additive Manufacturing and Reverse Engineering design and processes for the twin transition
Scientific Discipline Sector	ING-IND/16
CFU	2
Year	First
SUMMARY /GOAL	The course aim to provides PhD students with the knowledge about advanced Additive Manufacturing (AM) and Reverse Engineering (RE) processes mainly for new Repairing/Remanufacturing more sustainable solutions in circular industrial economy. In fact, the new Additive Manufacturing methods offer the best value-added, resource-efficient approach to end-of-life product recovery. The course project will be articulated in different topics: 1. Direct Energy Deposition (DED) solutions for repair and life extension. Among DED processes, Laser Powder Metal Deposition will be analysed in more detail because of its enormous capabilities, flexibility and efficiency.

DRIG

Course title	Smart sustainable manufacturing
Scientific Discipline Sector	ING-IND/16
CFU	2
Year	First
SUMMARY /GOAL	The major issue of sustainable manufacturing activities is the management of useful information: the way we choose data to measure may strongly change the perception of its nature and influence. Thus sustainability, which is an emerging paradigm in manufacturing, is now leading the most of the scientific efforts in defining the assessment of sustainability and the collection of significant measures of transition toward actions that satisfies the economic, environmental, social and technological targets. Smartness paradigm in manufacturing, on the other hand, is deeply tied to the information management and use, provided the Digital Twins as well as Cyber Physical Systems are mostly based on data get from sensing systems and on their elaboration to predict the evolution of systems simulated. The class will bring the students to understand the main driving issues in assessing and managing sustainable manufacturing in the light of a smart transition. At the same time will put major issues to come in order to stimulate students in their scientific career to deepen open issues still remaining on the subject from a technological perspective. Contents 1CFU. Manufacturing processes and the main factors of production: material and energy. Manufacturing and sustainability. Production systems and their sustainable management. Smart manufacturing paradigms: I4.0 and 5.0. 1CFU Criteria for modeling manufacturing processes and their critical variables. Cyber Physical System and Cyber Physical Social System. Measurement of the ecological footprint of a process: carbon and water footprint. Sustainability Assessment of manufacturing processes based on 1 and 2nd law of thermodynamics.

DRIG

Course title	Technological changes and transition perspective
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	First
SUMMARY /GOAL	The technological change is continuously increasing its pace. New technologies and business models are impacting the economic and social systems in a deep and unexpected way as well as social systems are adapting and reacting to these changes. The aim of the course is firstly to adopt the epistemological point of view for the technological determinism to examine how technology, economy, and society interact each other when a change in technology occurs. Some cases will be presented and discussed (asbestos cement, iron, and automotive technologies). Then, the transition perspective is presented to explain how such changes can determine long-term and wide impact. The type and nature of the transition are discussed. The structural and ideological nature of a transition will be described to support a full understanding of the phenomena. Some tools to operationalize ideologies are introduced. The green and digital transition will be examined adopting this perspective. A specific analysis for the transitions towards the smart city and the new space economy will be discussed with students.

DRIG

Course title	Business models for circular supply chains
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	First
SUMMARY /GOAL	This course will introduce the concept of circular supply chain and the the role played by business models to achieve a transitions towards a sustainable economy

DRIG

Course title	Lean production in the digital factory
Scientific Discipline Sector	ING-IND/17
CFU	2
Year	Second
SUMMARY /GOAL	The course provides PhD students with the core knowledge they need: i. to understand the concept of Lean Production (principles, models and tools); ii. to design and manage the process of continuous improvement of a smart production system; iii. to enable the Lean Transformation in the digital factory.

DRIG

Course title	Human-based Smart Manufacturing Systems
Scientific Discipline Sector	ING-IND/17
CFU	2
Year	Second
SUMMARY /GOAL	This course will introduce basic knowledge as well as advances in the description of the behaviour and of the knowledge and skills of the human component required in the new work environments

DRIG

Course title	Smart and sustainable last-mile logistics
Scientific Discipline Sector	ING-IND/17
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to provide the basic knowledge and advances on the principles and methods of freight and people last-mile logistics design and management in urban areas through innovative Industry 4.0 technologies.

DRIG

Course title	Management and Business research
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY /GOAL	This course aims to introduce PhD students to a scientific approach to the study of management and business issues. The focus is on equipping students with the fundamental knowledge and skills for undertaking research in managemen and business and to critically evaluate research conducted by others. The course is divided into four interrelated segments: problem formulation/conceptualisation, implementation, analysis, publication, and communication of research findings. Ethic issues will be further discussed

DRIG

Course title	From qualitative to quantitative methods in business research
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to provide PhD students with a set of building blocks for conducting, at the academic level, both quantitative and qualitative research in the areas of management, economics, and policy. As quantitative research, the course addresses three main issues of qualitative research. First, the course provides theoretical insights into different quantitative research methodologies and designs. Second, the course introduces PhD students to various methodologies for gathering data, observations, and evidence and for organising them in ways that can be used for quantitative analysis. Third, the course introduces PhD students to various quantitative methodologies – from regression analysis to text mining –to support PhD students in the development of practical skills as well as critical thinking for interpretation purposes. As to the qualitative research, PhD students will be introduced to the basic ideas behind the qualitative research in social science. Students will learn about data collection, description, analysis and interpretation in qualitative research. Qualitative research often involves an iterative process. The course will focus on the ingredients required for this process: data collection and analysis.

DRIG

Course title	Empirical research on sustainable innovation and resilience
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY /GOAL	This module will deal with empirical research in the fields of sustainable innovation and consumer behavior, with a specific focus on surveys (questionnaire development, administration, and statistical data analysis) as well as main approaches and tools firms can consider in assessing and managing supply chain risks in order to achieve resilience in their supply chains.

DRIG

Course title	Design and management of research projects
Scientific Discipline Sector	ING-IND/17
CFU	2
Year	First
SUMMARY /GOAL	This course provides essential knowledge, methodologies, and tools for designing and managing research projects. The main learning objectives are as follows: Guide participants in crafting successful proposals and developing comprehensive plans for research projects to capitalize on available funding opportunities. Focus on the objectives, methodologies, conditions, and best practices of major research programs. Familiarize students with the EU financial framework. Equip pstudents with the principles and competencies of project cycle management. Develop the ability to precisely define the objectives, purpose, and requirements of a project. Introduce principles, techniques, and tools for the design and planning of research projects. Enhance competencies in key project monitoring and control techniques. Familiarize students with the successful dissemination principles of research projects.

DRIG

Course title	Introduction to probability and statistical inference
Scientific Discipline Sector	MAT/05
CFU	2
Year	First
SUMMARY /GOAL	This course introduces the fundamental concepts of elementary probability theory and statistical inference. Topics include conditional probability, conditional expectation, discrete and continuous random variables, sampling and combinations of variables, the central limit theorem, statistical inferences for the mean and the variance

DRIEI

Course title	Inertial sensors
Scientific Discipline Sector	ING-INF/01
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to introduce the general concepts and applications of inertial sensors, as well as the technologies for their implementation, starting with the well-established ones and moving on to the most innovative with mid-low TRL. The course will start with an introduction to the fundamentals, operating principles, performance parameters, and main applications of inertial sensors. MEMS inertial sensors will be analyzed, showing also the most recent achievements at the state-of-the-art. The different configurations and operating principles of photonic gyroscopes will be discussed with a specific focus on miniaturization strategies. Some selected emerging technologies, including quantum inertial sensors, will be presented.

DRIEI

Course title	Design of optical fiber devices with Finite Element Method
Scientific Discipline Sector	ING-INF/02
CFU	1
Year	Second
SUMMARY /GOAL	The course will offer an insight into the finite element method (FEM) for the multiphysical design of optical devices. The course participants will be able, by the end of the course, to use COMSOL Multiphysics autonomously as design tool of optical fiber-based devices. Each lesson shall consist in lecture and numerical examples.

DRIEI

Course title	Electromagnetic design via professional softwares
Scientific Discipline Sector	ING-INF/02
CFU	1
Year	Second
SUMMARY /GOAL	The course proposes an overview of some professional softwares such as CST Studio Suite for the design of electromagnetic devices. Both antennas and microwave devices will be proposed for design and study, with particular focus millimeter and sub-millimeter wave antennas. The participants will learn how to design and simulate electromagnetic devices with many practical examples.

DRIEI

Course title	Green Photonics for a sustainable economy
Scientific Discipline Sector	ING-INF/02
CFU	1
Year	Second
SUMMARY /GOAL	The course aims at introducing some fundamental photonic technologies for sustainable energy generation and for energy saving. The topics of the course will be mainly introduced through theoretical lectures and hands-on computer simulations. The course will deal with green photonic devices such as solar cells and new photonic technologies for communication. Summary: Introduction to green photonics. Introduction to numerical simulation of photonic devices. Photonic devices for efficient communication networks. Sustainable energy generation: nanostructures for photovoltaics.

DRIEI

Course title	Antenna Technology for 5G communications: propagation arrays and integration
Scientific Discipline Sector	ING-INF/02
CFU	1
Year	Second
SUMMARY /GOAL	The course aims to introduce the fundamental concepts of antenna technologies for new generation telecommunication systems with a particular focus on beam steering and beam forming. The course includes the study of numerical methods and laboratory experiences for testing and characterizing antennas and antenna arrays. The course will be organized as follows: -Introduction; -Antenna elements and types: smart and reconfigurable configurations; -Implementation of antennas with CST Studio; -Characterization and test of antenna and array performance; -Radiopropagation, beam steering and beam forming for communication systems.

DRIEI

Course title	Exploring latest cybersecurity technologies and trends
Scientific Discipline Sector	ING-INF/03
CFU	2
Year	First
SUMMARY /GOAL	The course illustrates the emerging methodologies and technologies for the cyber security, with particular focus on (i) Internet, wireless and mobile networks, (ii) Cyber-Physical Systems and Social Internet of Things, (iii) Digital Service Chains, (iv) advanced mechanisms for data protection, user authentication, and access control, (v) Blockchain and examples

DRIEI

Course title	Management of future telecommunication systems via pervasive intelligence
Scientific Discipline Sector	ING-INF/03
CFU	2
Year	First
SUMMARY /GOAL	The course illustrates the emerging technologies and methodologies based on pervasive intelligence for the management of future telecommunication systems, with particular focus on: (i) the context of 5G and Beyond networks and the enabling technologies, (ii) traffic analysis at the mobile edge, (iii) anticipatory resource allocation at the edge, (iv) Radio Access Network slicing management, (v) practical examples.

DRIEI

Course title	Introduction to the Simplex Method
Scientific Discipline Sector	ING-INF/04
CFU	1
Year	First
SUMMARY /GOAL	Introduce students to modeling, solving, and interpreting real problems that can be reduced to linear optimization. To get familiarize with the mathematical formulation of a real world problem. To process and analyze known numerical methods for solving linear optimization problems as well as present appropriate geometric interpretations. To make aware the students about the applications of various forms of Linear Programming.

DRIEI

Course title	Deep learning
Scientific Discipline Sector	ING-INF/05
CFU	2
Year	First
SUMMARY /GOAL	The course intends to introduce students and practitioners to the field and applications of Deep Neural Networks. The course participants will be able to design and implement Deep Neural Networks to address various and different tasks autonomously. The lessons alternate theoretical lectures and implementation examples.

DRIEI

Course title	Machine learning
Scientific Discipline Sector	ING-INF/05
CFU	2
Year	First
SUMMARY /GOAL	The course will provide a broad introduction to machine learning. The course will cover Supervised learning, Machine Learning systems design and evaluation, Unsupervised learning, including clustering and dimensionality reduction. By the end of the course, the course participants will be able to design and implement Machine Learning-based applications autonomously. The lessons alternate theoretical lectures and implementation examples.

DRIEI

Course title	Rehabilitation Engineering
Scientific Discipline Sector	ING-INF/06
CFU	2
Year	First
SUMMARY /GOAL	The course aims to provide students with basic knowledge on design principles and methodologies, grounded in the scientific studies, on technologies for rehabilitation bioengineering, including wearable sensors, rehabilitation and assistive robotic systems, e-health applications.

DRIEI

Course title	Matlab recipes for measurement signal processing
Scientific Discipline Sector	ING-INF/07
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to present, with a “hands on” approach, a number of useful techniques to acquire and process measurement data, with actual implementation in Matlab. The programme of the course is intended to be adjusted on-the-fly, according to the actual background of the students (in order to avoid too simple or too advanced topics), and to meet actual topics of interest for their Ph.D. work.

DRIEI

Course title	Supervision and monitoring of renewable energy systems
Scientific Discipline Sector	ING-IND/31
CFU	1
Year	Second
SUMMARY /GOAL	The course aims to introduce the fundamental concepts for the monitoring of the electrical and energy performance of plants/systems based on Renewable Energy Sources (RES), notably photovoltaic systems, and for the diagnostics of anomalies or failures. 1) Supervision and monitoring systems for RES 2) Statistical tools for performance analysis of RES 3) Infrared analysis for the fault detection of RES

DRIEI

Course title	Micromagnetic modeling
Scientific Discipline Sector	ING-IND/31
CFU	1
Year	Second
SUMMARY /GOAL	This course provides an introduction to the micromagnetic modeling, from an interdisciplinary perspective focused on electrical engineering and physics, and gives the key-concepts for the following course on Spintronics Applications. Micromagnetic modeling is a major theoretical framework to analyze magnetic materials at the micrometer scale and below. Students will be introduced to basic concepts of nanomagnetism and micromagnetics. They will learn how the competing micromagnetic energies affect the magnetic state and the equations which govern the dynamics of the magnetization. They will also learn the fundamentals of the numerical implementation of micromagnetism and perform numerical simulations by means of a micromagnetic solver, using MATLAB for post-processing the output data. Each lesson shall consist in a lecture with numerical examples.

DRIEI

Course title	Spintronics applications
Scientific Discipline Sector	ING-IND/31
CFU	1
Year	Second
SUMMARY /GOAL	This course follows the introduction provided in the course of Micromagnetic Modeling and deals with basic concepts of Spintronics, from an interdisciplinary perspective focused on electrical engineering and physics. Spintronics represents an emerging research frontier with the potential to impact a broad range of applications. Students will use micromagnetic models to study and design spintronic devices for applications such as storage, microwave oscillators and detectors. They will also perform numerical simulations by means of a micromagnetic solver and use MATLAB for post-processing the output data. Each lesson shall consist in lecture and numerical examples.

DRIEI

Course title	Power Systems Simulation Tools
Scientific Discipline Sector	ING-IND/33
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to provide information on the data management and results interpretation of power system simulation tools for the different analysis of load flow, continuation load flow, short circuit, small signal stability, dynamic stability. The classroom activities will deal with: • Operation of power systems • Models of regulation • Explication of data for different analysis • Building of a co-simulation environment • Examples Scientific papers and books on the selected arguments will be used as reference. The examination method is represented by a synthetic report on a chosen topic.

DRIEI

Course title	Electric power system markets and planning
Scientific Discipline Sector	ING-IND/33
CFU	1
Year	Second
SUMMARY /GOAL	The aim of the course is to provide information about the organization of electric power system planning and operation with different levels of electricity markets for the provision of energy and services. The classroom activities will deal with: • Power system evolution • Power system development planning and scenario approach • Power system regulation services and reserves • Structure of electricity markets, coupling, grid models, and new regulation services Scientific papers and books on the selected arguments will be used as reference The examination method is represented by a synthetic report on a chosen topic.

DRIEI

Course title	Numerical Methods for Big Data
Scientific Discipline Sector	MAT/08
CFU	2
Year	Second
SUMMARY /GOAL	The course will describe the numerical methods that facilitate the analysis of big data, network analysis and many machine learning applications. Their implementation in Matlab will be addressed, together with the use of modern Matlab toolboxes for large and sparse data; applications to the solution of real-life problems will be considered. Each lesson shall consist in lecture and numerical examples.

DRIEI

Course title	Numerical Methods for Multidimensional Differential Problems
Scientific Discipline Sector	MAT/08
CFU	1
Year	Second
SUMMARY /GOAL	This course will provide an advanced level overview on the numerical solution of partial differential equations and computational models for differential problems. Within a rigorous mathematical setting, the major classes of numerical methods will be analyzed and critically discussed. Consistency and stability will be also accounted providing essential guidelines for the choice and implementation of numerical methods for differential problems. The course syllabus follows: • Transport equations. Scalar transport problem, a priori estimation. System of hyperbolic linear equations. Finite difference technique, scalar equation discretization and discretization of a system of hyperbolic linear equations. Boundary conditions. • Equivalent models for transport equations. • Kinetic BGK-like models. Kinetic models for hydrodynamics and traffic laws. Convergence and Stability. Computational aspects. • Description of parallel computing structures and strategies. Shared memory VS distributed memory.

DRIEI

Course title	Research Methodology
Scientific Discipline Sector	ING-IND/31
CFU	2
Year	First
SUMMARY /GOAL	This course aims at providing PhD students with the knowledge of fundamentals of Research Methodology and how to use them effectively in their own scientific research. Case studies and examples are inserted where required

DCMCEI

Course title	Innovative and recyclable methods and materials for Civil Engineering applications
Scientific Discipline Sector	MAT/07
CFU	2
Year	First
SUMMARY /GOAL	The main contents of the course are: – Multiscale methods for the design and characterization of innovative and recyclable materials; – Thermo-hygro-mechanical properties of innovative and bio-inspired materials for Civil Engineering; – Damage effects induced by temperature, mechanical stress and chemical phenomena; – Design and characterization of materials with complex structures based on data modelling approaches.

DCMCEI

Course title	Low carbon structural design and retrofitting of concrete infrastructures using advanced composites
Scientific Discipline Sector	ICAR/09
CFU	2
Year	Second
SUMMARY /GOAL	The main contents of the course are: – Introduction to low-carbon structural design. – Fibre-Reinforced Materials in civil engineering construction. – Innovative reinforcement for resilient concrete structures. – Retrofitting concrete structures using advanced composites.

DCMCEI

Course title	Innovative evaluation techniques to support the implementation and management of civil constructions
Scientific Discipline Sector	ICAR/22
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide an essential overview of the main evaluation techniques to support decisions in local interventions, also with reference to public-private partnership models. Contents in summary form: – Estimate and innovative tools for the construction of civil works; – Financial analysis and economic analysis (ACB) for the evaluation of investments and the estimate of the impact on the community; – Multi-Criteria Decision Analysis (MCDA) to support decisions in complex contexts: the construction of multidimensional indicators for the implementation and management of civil works.

DCMCEI

Course title	Practical Course in physical modelling for coastal engineering
Scientific Discipline Sector	ICAR/02
CFU	2
Year	Second
SUMMARY /GOAL	The Practical Course in Coastal Engineering gives Ph.D. students an insight into physical experiments related to coastal engineering research. The focus is on the planning, implementation and evaluation of physical experiments in maritime laboratories on both 2d and 3d small scale models. Scaling criteria of both hydrodynamic and morpho dynamic quantities, measurement techniques, data acquisition, analysis and post processing will be the main contents of the course. Topics: – Introduction to measurement and experimental techniques in coastal engineering. – Planning and execution of model tests - Scaling criteria. – Acquisition and analysis of measurement data using ultrasonic and resistive wave gauges, pressure transducers, ADV, bed profiler, load cells, laser scanner, lidar, photogrammetry, etc.; – Statistical description of the generated waves in time domain. – Parameterization using characteristic wave parameters and analysis of sediment transport processes in scaled physical models.

DCMCEI

Course title	Meteomarine forcing and design of maritime constructions
Scientific Discipline Sector	ICAR/02
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide the first basic preparatory knowledge of the marine environment (study of waves, currents, transport, sediments, etc.) and the elements necessary for the design of maritime works, both port and coastal defense against erosion. The digital contribution is given by the following elements: – application of AI algorithms for the analysis and modelling of wave motion data; – integration of multiple data sources (in situ, remote sensing, etc.) to improve the modelling of the Adriatic Sea; – use of AI for the prediction of marine dynamics, including extreme events such as hurricanes and tsunamis and their impact on morpho dynamics.

DCMCEI

Course title	Elements of digital transition in civil engineering
Scientific Discipline Sector	ICAR/02
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide elements of digital transition tools in water engineering and the concept of Digital Twin and Digital Water Service. The students were introduced to advancements in data acquisition, storage and representation with the latest methodologies developed from technical-scientific research based on complex network theory, machine learning and multi-objective optimization. The final aim is to provide PhD students with effective and transferable products that implements efficient processes to face various technical issues. Advanced applications to Water Distribution Networks (WDNs) will be used as benchmarks, involving students in applying Digital Water Services to integrate the concept of Digital Twin, tailored for WDNs, with well-established algorithms and methodologies, to support solving WDN life-cycle management issues.

DCMCEI

Course title	Innovation of business models in the civil infrastructure sector
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY /GOAL	This module aims to provide concepts, approaches and techniques for the generation, management, analysis and innovation of business models in the civil infrastructure sector. Specifically, during the course the main reference frameworks for the definition of a business model will be presented as well as the patterns of existing business models with particular focus on the civil infrastructure sector. The innovation dynamics of business models will also be explored in depth, providing useful elements for structuring the evolution process, especially in reference to the adoption of the most recent digital technologies enabling a digital innovation path in the civil infrastructure sector. The module will include alternating theoretical lessons with practical sessions (examples, case studies and project work). Below is the summary structure of the module: – Business models (definitions and frameworks). – Business model patterns (with focus on the civil infrastructure sector). – Innovation of business models and digital innovation in the sector.

DCMCEI

Course title	Innovative approaches and digital tools for ecological land planning
Scientific Discipline Sector	ICAR/20
CFU	2
Year	Second
SUMMARY /GOAL	The contribution of land planning to climate adaptation and mitigation strategies: – The challenges of climate change to land planning; – The role of cities in adaptation and mitigation policies; Approaches and tools for ecological planning: – Different interpretations of the ecological transition in the plans: modernization vs. capitalization; – Nature-based solutions in city planning; – The urban bioregion: eco-territorial approach, ecosystem services, multifunctionality; Potential and critical elements of the digital transition to support ecological planning: – GIS/webgis, open data, social networks, etc. to support inclusive approaches to planning, coordination between Public Administration sectors dealing with territorial governance, sharing and transparency of decisions and monitoring systems; – Digital divide, difficulty in involving users in the creation and use of digital systems, data updating.

DCMCEI

Course title	Advanced Transportation Accessibility-Equity Assessment
Scientific Discipline Sector	ICAR/05
CFU	2
Year	First
SUMMARY /GOAL	This course delves into the field of Transport Accessibility and Equity Assessment, providing an in-depth exploration of key concepts, methodologies and tools. The aims of the course are: – Exploring the Principles of Accessibility-Based Transportation Planning (e.g., 15 minutes city); – Utilizing Evaluation Tools and Performance Indicators for Measuring Progress Toward Transportation Equity Goals (e.g., threshold measures, gravity measures, PTAL, Lorenz Curve, Gini Index); – Provide with transportation policy evaluation tools that account for the costs and benefits of equitable planning (e.g. through cost-benefit analysis and multicriteria evaluations). The final scope is to equip students with advanced analytical tools and critical perspectives essential for addressing the interplay between transportation systems and social equity in diverse territorial contexts.

DCMCEI

Course title	Open Source and Innovative tools for simulating transport systems
Scientific Discipline Sector	ICAR/05
CFU	2
Year	Second
SUMMARY /GOAL	The aim of this course is to equip participants with a good understanding of innovative and Open-Source tools specifically designed for simulating transport systems to analyse performances of new technologies and digitalization of transport infrastructure and systems. The course will delve into: – the role of digital twins in simulating real-world transport scenarios. – advanced methodologies for harnessing and analysing extensive datasets (Big data) to understand mobility phenomena. – command-line interface (CLI) tools, primarily controlled by typing commands (e.g. SUMO, Python, R). – graphical user interface (GUI) tools, primarily controlled by point and clicking (e.g. AequilibraE, QGIS). – web application programming interfaces (API) and web user interface (WUI) tools; During the course participants will gain knowledge on these tools to mapping and simulate transport system, fostering a good grasp of their application in achieving efficiency and sustainability within the mobility planning sector.

DCMCEI

Course title	Innovative techniques and methodologies for the reuse of materials in road, railway and airport constructions
Scientific Discipline Sector	ICAR/04
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to illustrate the current techniques and technological innovations relating to the management and use of recycled materials in the construction of mobility infrastructures: – construction of road embankments; – recycling of milled asphalt; – use of materials from other production chains (used tyres, plastics, ...) for the production of road construction materials; – techniques and technologies for maximizing the use of excavated earth and rocks; – platform water management for traffic and environmental safety; – alternative materials for complementary works.

DCMCEI

Course title	Road infrastructure for intelligent mobility
Scientific Discipline Sector	ICAR/04
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to illustrate the main techniques and technologies for the construction and management of road infrastructures in the presence of connected, automatic and semi-automatic vehicles (Smart roads, Smart tunnels, ITS, C-ITS, adaptive lanes, etc.). The problems linked to the technological transition will also be illustrated with reference to both the existing road heritage and the coexistence of vehicles with different technological capabilities..

DCMCEI

Course title	Complex Network Theory: Theory, Methods and Applications
Scientific Discipline Sector	ICAR/02
CFU	2
Year	First
SUMMARY /GOAL	The integration of both mathematical and technical tools, as well as the growing availability of data, make it possible to study and interpret an enormous number of complex systems, where the main component is topology, that is, the way in which elements are connected and interact with each other. This course offers an overview of all the Complex Network Theory tools and their use in the study and analysis of real systems from a topological perspective, starting from water systems, which represent complex networks composed of several interconnected components, structured in non-trivial configurations, whose behavior is largely influenced by their connective structure, spatial limits, and interactions between components. This course aims to address the following points: – Introduction to CNT. Euler and the problem of the Königsberg bridges. Graphical representation and adjacency matrix. Basic concepts and study of topological properties. – Centrality metrics as tools to identify the most important elements in complex real systems. Degree, Betweenness, Closeness and Harmonic. – Construction of predictive models for understanding complex real systems. How the connective structure is fundamental to determine vulnerability and robustness. Regular, random, small-world (principle of six degrees of separation) and scale-free networks. – Communities and clustering for system analysis and management. Detecting the presence of communities is essential for discovering the internal connections of complex structures and facilitating practical applications in many disciplines. – Time series and their representation in CNT: Visibility algorithms. – Overview of the different fields of application: social systems, road networks, distribution systems, biological organisms, technological networks, computer networks, epidemiology, etc.

DCMCEI

Course title	IoT Technologies for Digital Transition
Scientific Discipline Sector	ING-INF/03
CFU	2
Year	First
SUMMARY /GOAL	Introduction to IoT – Overview of Computer Networking and Internet Eco-system – IoT Devices design and development – IoT Communication Cycle – Application of IoT in Civil Infrastructures – Importance of Smart Infrastructure Sensors and Data Acquisition for Civil Infrastructures (3 Hours) – IoT Components and Scope – Role of Sensors in IoT Applications – Data Acquisition Techniques – Sensor Deployment in Infrastructure Monitoring Concepts IoT Communication Protocols and Standards (6 Hours) – 6lo Stack protocols – Wireless Technologies for Infrastructure – Scalability and Reliability Considerations Modern Network Architecture: Clouds and Fog (3 Hours) – Overview Of Cloud Computing Concepts – Edge and Fog Computing – Cloud Services (SaaS, PaaS, and IaaS) – Cloud Deployment Models (Public, Private, Community, and Hybrid cloud) – Cloud Architecture (NIST and ITU-T) IoT Security (5 Hours) – Fundamental Security Requirements – European Telecommunications Standards Institute (ETSI) Security Perspective – IoT Security and Privacy Requirements Defined by ITU-T – IoT Security Framework – Cloud Security o Security Issues and Concerns o Data Protection in the Cloud

CTI

Course title	Theories and methods in structural design: modeling and experimental issues
Scientific Discipline Sector	SSD: ICAR/08
CFU	2
Year	First
SUMMARY /GOAL	The shape of masonry constructions and the influence of the curvature in the load bearing capacity of arches, domes and vaults. Seismic actions and masonry constructions. Mechanical behavior of masonry: heterogeneity, different behavior in tension / compression, non-linear mechanical response, anisotropy, failure modes, damage. Modeling strategies: micromechanical models, FEM and DEM implementation of micromechanical models, macro-mechanical models, multiscale models, NT (No-Tension) and RNT (Rigid No Tension) models, macro-elements. Limit Analysis: static and kinematic approaches. From the static approach of Limit Analysis to the relation between shape and structures in masonry arches and vaults (and back to graphic statics).

CTI

Course title	Generative Algorithms: digital tools for parametric design and assessment of structures
Scientific Discipline Sector	SSD: ICAR/09
CFU	2
Year	First
SUMMARY /GOAL	New technologies are changing the way engineers work within the construction sector. Newly developed software solutions have provided effective methods to explore the design space at the interface between Structural Engineering and Architecture, allowing more efficient design strategies. The course aims to explore the potentials of new digital tools based on generative algorisms. The course is organized into four main parts in which both theoretical and practical aspects will be illustrated: 1) Theoretical aspects of the Generative Scripting; 2) Introduction of the Python interpreter component for Grasshopper (Rhino 3D), which allows to execution of dynamic scripts; 3) Introduction to Structural Optimization; 4) Workshop: the students will be divided into groups, and they would be defining helpful generative algorithms in their research topic.

CTI

Course title	Contextual Design and Heritage: identity and material culture of the territories
Scientific Discipline Sector	SSD: ICAR/13
CFU	2
Year	First
SUMMARY /GOAL	The course aims to explore the role of design in the enhancement of material culture as recommended by the 2003 UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage, with a particular focus on Southern Contexts. The "intangible cultural heritage means the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage". The Heritage dimension proposed by the UNESCO Convention is a "phenomenal extension" of the field of knowledge, conservation, enhancement and re-activation of material culture in which contextual design is developing a prominent role. Contextual Design is an important field of contemporary research developed in North Europe, in the Design Academy of Eindhoven. The aim is to investigate the meaning of the material and immaterial artifacts of design in relation to the identities of the territories and to the historical and cultural stratification that distinguishes them. Contextual Design and Cultural Heritage thus become a strategic combination to face the modern challenges of enhancing territorial contexts against the current phenomena of globalization and spectacularization of culture.

CTI

Course title	Design for Historical and Contemporary Heritage Landscapes
Scientific Discipline Sector	SSD: ICAR/14
CFU	2
Year	First
SUMMARY /GOAL	The Faro Convention extends the idea of heritage from the architectural dimension to the dimension of city and landscape, recognizing together with the value of the single artifact the value of the relationship between artifacts in urban or natural context. Furthermore, the Convention consider as heritage non only the “extraordinary” but also the “ordinary” architecture, not only the ancient but also the ‘modern’ architecture. The notion of heritage landscape results from this new idea of heritage. The course will deal with the themes of the project for the preservation and valorization of the heritage landscapes, both historical and contemporary, both extraordinary and ordinary. The heritage landscapes are not only the archaeological and historical landscapes but also, for example, the urban landscape of the ‘modern’ city, that of the social housing district as well as that of the disused industrial plants. In this perspective, the course will deal with theories and design techniques useful for the transformation of the heritage landscapes, necessary to preserve, valorize and resignify them.

CTI

Course title	Theories and methods of design for the Antique
Scientific Discipline Sector	SSD: ICAR/14
CFU	2
Year	First
SUMMARY /GOAL	The first part will be structured into four thematic sections: the first, by investigating the contributions offered by the Masters of Architecture between the XIX° and XX° centuries and deducing their theoretical background, will try to outline the general principles underlying the main points of view that connote contemporary architectural research; the other three will be thematically articulated and focused on the relationships between "Antique and Landscape", "Antique and City", "Renovation and Museography", and will see the compositional analysis of some exemplary contemporary works, in order to recognize methods and techniques of the design for the Antique. The second part will be devoted to the exercises. They will be carried out in the modality of an intensive design workshop, dealing with and developing a project concerning the main topics of the course.

CTI

Course title	Historical research and study of the Ancient architecture
Scientific Discipline Sector	SSD: ICAR/18 – L-ANT/07
CFU	2
Year	First
SUMMARY /GOAL	Ancient architecture is almost always in a state of ruin. His study, aimed at formulation of reliable hypotheses of reconstruction of the building, must be based on integrated survey methodologies that use the detailed analysis of the ancient ruined building as an essential knowledge base. They are taken into consideration therefore, besides to the observations derived from the results of the architectural survey, also any iconographic testimonies from other sources, such as vascular painting, frescoes, bas-reliefs, images on coins, etc. The building and its construction and morphological details, as well as, when present, his architectural sculpture must then be compared with others contemporary architectures, in order to include it in its historical-geographical context. The course therefore aims to present some completed or ongoing architectural research that can effectively illustrating the research method mentioned above. In particular, the following case studies will be addressed: - The Arch of Trajan in Leptis Magna - The reconstruction of urban planning of Kos - The Curia in Leptis Magna - Architectural sculpture in the anastylosis of ancient buildings - Urban planning in Ionia and Caria between the archaism and the Hellenistic age - Architectural and decorative models in the mausoleums of the imperial age in Libya - The Hellenistic theatre in Mytilene - The townscape in the figurative culture of Greek and Roman times - The urban planning ant the agora of Byllis (Albania) - The Cistern in the agora of Byllis, analysis of the typology and of the constructive aspects.

CTI

Course title	Problems and methods of contemporary restoration
Scientific Discipline Sector	SSD: ICAR/19
CFU	2
Year	First
SUMMARY /GOAL	The educational objective of the course of Problems and methods of contemporary restoration is to illustrate the general lines of the main ways of understanding restoration and to provide PhD students with the historical-critical tools to develop an autonomous and conscious thought regarding the themes and nodes problematic of the discipline, with particular regard to the conceptual elaborations and experiences that open from the second post-war period to contemporary debate. There will be lectures and exercises, mutually complementary. Through the lectures the methods will be deepened, the knowledge of the theoretical and cultural foundations of restoration will be increased and strengthened and the ability to understand the conceptual nodes of the discipline will be developed in order to direct PhD students to achieve a capacity for critical re-elaboration of the acquired knowledge. Through the exercises the ability to apply knowledge and understanding will be developed and verified. The course is divided into two parts. The first part of the course will be divided into two thematic sections: the first will present the philosophical and cultural foundations of the discipline; in the second, some key issues of the contemporary debate will be addressed, such as the relationship between “restoration and creativity” in the “old and new” dialectic. The second part will be dedicated to exercises. These will take place in the form of discussions which, through comparison, will help PhD students acquire an autonomous ability to apply the knowledge acquired through analytical and critical tools useful for interpreting the different theoretical positions and evaluating their operational implications. The attribution of training credits will take place through a final test, aimed at verifying the acquisition of knowledge and skills by the PhD student. The assessment will also take into account participation in the training activities carried out.

CTI

Course title	Theories and techniques of the project for the fragile cities and territories
Scientific Discipline Sector	SSD: ICAR/14
CFU	2
Year	First
SUMMARY /GOAL	The recent disastrous phenomena, accentuated by atmospheric changes as well as by neglect and improper transformation processes, have highlighted the fragility of our cities and our territories, especially those of the so-called “inland areas”. The awareness that not only human lives and production activities are at risk but also the identity of the places is growing stronger and, for this reason, a paradigm shift for the safety and risk mitigation project is required. The course will illustrate an innovative approach aimed to combine Safety and Identity, based on the conception of the project of mitigation of risks (seismic, hydrogeological) as an opportunity of strengthening of the identity characters of fragile cities and territories. According to this approach, the safety works built in order to mitigate the hydrogeological risk can define a place in the landscape as well as “monumentalize” its natural forms. The project of mitigation of the seismic risk of the urban fabric of the Apennine cities could be an occasion to renovate the form of the city itself and its spaces. Indeed, combining safety and identity means convert the technical forms of the safety project into architectural forms, capable to exalt the characters of the places that they transform.

CTI

Course title	Stereotomic Design. New frontiers of stone architecture
Scientific Discipline Sector	SSD: ICAR/14
CFU	2
Year	First
SUMMARY /GOAL	The course aims to show the unexpressed potential of the structural stone for contemporary architecture. The whole course will be divided into three parts: a first historical introduction and evolution of stereotomic architecture; a second part relating to the three-dimensional infographic parametric/variational modeling techniques of complex vaulted spaces; and a last part relating to the realization of design' projects by the students reviewed by the teacher. The best projects will be 3D printed or real-dimension built and exhibited in the most important trade fairs of the sector.

CTI

Course title	The architecture of construction
Scientific Discipline Sector	SSD: ICAR/12
CFU	2
Year	Second
SUMMARY /GOAL	The course includes a first part with focus on the Form of Construction, i.e. the formal codes that constitutes the basic topics of structural forms; the second part deals with the knowledge of structural elements and the corresponding compositional techniques. The formal fundamentals comprise essentially the masonry wall system, the trilith system and the frame system, which are declined in specific and possible variations, depending on the use of materials and production techniques. At the same time, other formal principles focus on covering systems: the flat roof, the pitched roof, the vault, the dome. The course starts with a historic excursus that explains the origins of these structural fundamentals, the consolidation processes and the development due to the strengthening of techniques. A special attention shall be given to the best practices of the 20th century, in circumstances where the structural conception assumes a particular relevance in meeting the needs of "the architecture of techniques", i.e. skyscrapers, factories, commercial warehouses, religious buildings etc.

CTI

Course title	The architecture of structural forms
Scientific Discipline Sector	SSD: ICAR/14
CFU	2
Year	Second
SUMMARY /GOAL	The didactic project of the course assumes the relationship between space and the constructive forms of architecture as a problematic core, through a point of view that recognizes construction as the most powerful expressive resource for the representation of the spatial character of buildings. The thought on the structure, therefore, seems to be problematized in a dialectical tension between the disciplines of architecture and engineering, whose common language is that of matter and its possible formal definitions. The purpose of the course is to develop a particular approach to research on architectural design that is able to recognize, problematically, the relationship between space and the design of its structural systems, from type to construction. By declining the constructive paradigms of history and their cultural areas of reference, it is possible to identify some interpretative lines that feed the most recent structural experiments on matter, between the definition of its possible forms and the search for their own figurative identity. Just think of the research on the forms of reinforced concrete carried out in Switzerland since the beginning of the twentieth century, where the technical forms of the structure (also in the construction of bridges and infrastructure works) exceed their aesthetic autonomy, interpreting the relationship with the landscape in which they are located. Between Architecture and the Art of structures

CTI

Course title	Analysis and representation techniques for architectural research
Scientific Discipline Sector	SSD: ICAR/17
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to stimulate a critical attitude in the study of the city and architecture, providing to the young researcher a repertoire of analysis techniques and representation models to support research. The techniques of survey of the existing, laser scanner and photo-modeling, are joined to those of the inexistent, graphic analysis and graphic reconstruction, providing the tools and methods for a research of architectures in praesentia that can be studied and analyzed also metrically, that those in absentia designed and never realized. The course aims to analyze and graphically return the different components of architecture and the city, and with the tools of drawing and modeling investigate the historical / evolutionary process or the ideation / composition process too. These are fundamental cognitive moments for the study of an architecture or a part of the city and at the same time to analyze the complex personality of its author. Practical exercises alternate with lectures encouraging young researchers to use the techniques of analysis and graphic representation, articulating and stimulating their critical skills in reading an architecture and / or the city or a portion of it.

CTI

Course title	Historical research and study of contemporary architecture and city
Scientific Discipline Sector	SSD: ICAR/18
CFU	2
Year	Second
SUMMARY /GOAL	The course is divided into an institutional part of the program and in an experimental part, implemented in the modalities of the Laboratory, within which will be provided some exercises aimed at strengthening the student's critical skills starting from a basic training about the methods and materials for historical research in the second half of the twentieth century. The course aims to provide students with a correct study methodology aimed at acquiring a historical-critical knowledge of the history of contemporary architecture, from the origins of modern architecture to current architectural trends, with particular attention to the widespread ideas of Italian tendency. and, in particular, to the figure of Aldo Rossi and the masters who revolve around the editors of the Casabella of Rogers, also and above all in relation to the worldwide resonance that they had within the architectural debate after World War II.

CTI

Course title	The post-growth paradigm in planning research
Scientific Discipline Sector	SSD: ICAR/21
CFU	2
Year	Second
SUMMARY /GOAL	The educational objective of the course The post-growth paradigm in planning research is to offer PhD students the tools to understand the complexity of the contemporary world and acquire the ability to develop an autonomous and conscious thought with respect to the problematic issues and challenges that it arises. The course therefore aims to deepen the main phenomenologies of the post-growth paradigm in the city and in the territory, and at the same time discuss the lines of research that the disciplines of the territory, and in particular urban planning, have started in recent decades. There will be frontal lectures and exercises, closely integrated, that articulate the course in two parts. The first part of the course will be dedicated to thematic lectures, in which the themes of the post-growth paradigm, its causes and material manifestations will be deepened; moreover, the paths of the contemporary urban research will be outlined, in the directions of a renewed relationship with the existing, of the valorization of the territorial heritage, of the integration and contamination with the disciplines that deal with the themes of sustainability and climate change. The second part will be dedicated to exercises to be developed with reference to specific case studies representative of current research. These will take place in the form of interlocutions that, through comparison, will help doctoral students to acquire an autonomous ability to apply the knowledge acquired through analytical and critical tools useful to interpret the different theoretical positions and evaluate the operational consequences. The attribution of training credits will take place through an interview, aimed at verifying the acquisition of knowledge and skills by the doctoral student. In the evaluation will also take into account the participation in training activities carried out.

CTI

Course title	Theory of Formativeness
Scientific Discipline Sector	ICAR/14
CFU	2
Year	First
SUMMARY /GOAL	It seems lost today, in architecture as generally in arts, a unitary point of view on which to found a theory on. That civil conscience that has always been the basis of the art of building seems no longer part of the collective heritage. This condition is recognizable in the contradictory experience of contemporary architecture. For this reason, the class aims to try to outline a "classical" theory of architectural research; a classicism that does not renounce, rather it investigates, the culture of modernity, trying to measures itself against this alleged contradiction. All the architecture that we can include within the “classic” experience (that we can also define “rational experience”) is characterized by a peculiarity: the intelligibility of forms, along with we define a method of formativeness. According to this idea of architecture, there’s no advancement of forms without an advancement of knowledge - without an increasingly higher level of self-awareness. Hence the need for a theory of architectural research. The method of formativeness we want to investigate regards three major chapters of architecture: The relationship among architecture, city and landscape; The “construction issue”; The question of the project with the Ancient.

CTI

Course title	AI and Creativity
Scientific Discipline Sector	ICAR/14
CFU	2
Year	First
SUMMARY /GOAL	Artificial Intelligence is an emerging technology which is changing many creative sectors. Lots of AI-generated pictures of imaginary architectures are nowadays spreading on the web and on social media. But how can AI really influence the architectural field? Given its revolutionary significance, it is important that architects learn more about Generative AI, understanding its possible useful applications and developing at the same time a critical awareness about its usage and its ethical implications. The course is divided into 3 parts, both theoretical and practical: 1) Theoretical introduction about Generative Artificial Intelligence; 2) The introduction of Generative AI in the design process; 3) Practical session: students will learn how to use the AI Midjourney and will work on a personal project.

DRISA

Course title	Spatio-Temporal dynamics of lasers: modelling and applications
Scientific Discipline Sector	FIS/03
CFU	2
Year	First
SUMMARY /GOAL	The objectives of the course are: i) to describe the dynamics of lasers (and nonlinear optical devices) including coherent effects; ii) to describe spatiotemporal dynamics in the paraxial approximation; iii) to understand applications to pulse generation, multimode coherent dynamics, mode-locking, solitons and optical frequency comb (OFC) formation; iv) to apply gathered knowledge to semiconductor laser of notable relevance (e.g. quantum dot lasers, quantum cascade lasers).

DRISA

Course title	Mathematical Models for High Frequency Analysis
Scientific Discipline Sector	MAT/05
CFU	1
Year	First
SUMMARY /GOAL	The main goal of this course relies in introducing some mathematical models related to the study of wave propagation in continuous media in the regime of high frequency. Some arguments of asymptotic analysis will be discussed. Particular emphasis will concern the study of thin elastic structures in high frequency vibrations.

DRISA

Course title	DoE and Robust Design applied to setup optimization for numerical and experimental testing
Scientific Discipline Sector	ING-IND/14
CFU	2
Year	First
SUMMARY /GOAL	The aim of the course is to provide skills in the definition of statistically robust setup and analysis of experimental and/or numerical plans in order to reduce the impact of the noise.

DRISA

Course title	Coding Theory
Scientific Discipline Sector	MAT/03
CFU	1
Year	First
SUMMARY /GOAL	The aim of the course is to present the theory of error correcting codes and the mathematical principles they rely on, with special regard to their application to deep-space communications.

DRISA

Course title	Identification and propagation of optical photons in different media
Scientific Discipline Sector	FIS/01
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide the student with advanced knowledge of radiation measurements and detection techniques, from classic scintillation detectors to Silicon Photomultiplier devices. Scintillator materials are widely used in particle physics for ion identification and energy measurements. Next-generation space missions will employ plastic scintillator detectors (PSDs) equipped with the new Silicon Photomultipliers (SiPMs) technology to read out the scintillator light emission. Scintillator based detectors are also widely used for radiation monitoring for environmental or industrial purposes. The course requires an elementary background in radiation measurements, radiation-matter interactions and basic electronics.

DRISA

Course title	High-energy particle physics instruments and methods for space environment
Scientific Discipline Sector	FIS/01
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide an overview of basic principles of particle physics and of the main detectors used for space applications. Moreover, the explanation of the environmental verification strategy aims to give the students a complete overview of the steps needed to take a detector from construction to a correct on-orbit operation.

DRISA

Course title	Spacecraft Structural Dynamics & Loads
Scientific Discipline Sector	ING-IND/04
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to explain basic notions as well as some advanced concepts about structural dynamics and its importance in the development of the spacecraft structures (design, analysis, and test). Both numerical methods and experimental results will be presented.

DRISA

Course title	Hypersonic aerothermodynamics modelling and simulation
Scientific Discipline Sector	ING-IND/06
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to provide fundamentals of the physics, chemistry, and gas dynamics of high-temperature gases in the context of hypersonic flows. The course provides an introduction to gas dynamics of high temperature gases with a specific emphasis to thermochemical non-equilibrium and gas surface interactions with examples of accurate numerical simulations.

DRISA

Course title	Optical communications for space
Scientific Discipline Sector	ING-INF/02
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide an overview of some of the recent technologies related to optical/photonic communication for space. Participants will acquire the related knowledge through theoretical lectures and numerical examples.

DRISA

Course title	Space Commercialization
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to develop knowledge about the market challenges and the business opportunities offered to the new generation of European space entrepreneurs by the emerging space economy.

DRISA

Course title	Space Economy: past, present, future
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	Second
SUMMARY /GOAL	The objectives of the course are: i) to explain the evolution of the space industry since its inception; ii) to recognize the current trends and challenges of the space sector; iii) to identify humanity's short-term and long-term future ambitions in space, iv) to outline the role of Italy and Europe in the global Space Economy.

DRISA

Course title	Integrated Photonics for Space
Scientific Discipline Sector	ING-INF/01
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide an overview of some of the recent technologies related to integrated photonics for space applications. Participants will acquire the related knowledge through theoretical lectures and application examples.

DRISA

Course title	Introduction to space flights
Scientific Discipline Sector	ING-IND/05 – ING-IND/35
CFU	2
Year	Second
SUMMARY /GOAL	The purpose of this class is to provide students with a wide range of topics relevant to specific aspects of spaceflight. The class will be integrated with on spot lectures by astronauts, industry/agency representatives who will provide an overview of their experience, functional to the class objectives.

DRISA

Course title	Space Logistics
Scientific Discipline Sector	ING- IND/35
CFU	2
Year	Second
SUMMARY /GOAL	The aim of the course is to provide comprehensive introductory knowledge about the theory, practice, and advanced ideas of implementing space system design to guarantee operability and supportability, and on the management of the flow of materials, technologies, services, and information needed throughout a space system lifecycle.

DRISA

Course title	Hydraulics for Aircraft
Scientific Discipline Sector	ING-IND/08
CFU	2
Year	Second
SUMMARY /GOAL	The course will enable PhD students to gain knowledge about conventional and novel hydraulic systems employed in aircraft for fuel metering and for flight control. In addition, students will master Simulink simulations of these systems. The acquired knowledge can be transferred to the study and simulation of hydraulic components and systems employed in industry and in the transportation sector.

DRIME

Course title	Acoustics and thermoacoustics
Scientific Discipline Sector	ING-IND/09
CFU	2
Year	First
Summary / Goal	Coupling between acoustic waves and flames has become a central issue in the development of many modern combustion systems because of both environmental issues (noise) and the destructive interactions which acoustics can generate in combustors. Numerical tools are essential in many flames/acoustics studies but a theoretical background in acoustics and especially in acoustics for reacting flows is mandatory to tackle such problems. This course presents the fundamental concepts of acoustics and thermo-acoustic instabilities together with instability control strategies. Possibilities of data-driven approach for optimal design of stable combustion chamber will be also presented. The course is an alternation of theoretical presentations and practical work. It is divided into 5 lectures and a practical hands-on. 1) Fundamental of acoustics: theory, modelling and measurement techniques. 2) The thermo-acoustic combustion instabilities 3) Flames as acoustic element: Flame transfer functions/Flame describing functions 4) Controlling of thermoacoustic instabilities: passive and active control strategies 5) Data-driven methods for optimal design. 6) Simple hands-on.

DRIME

Course title	Hydraulic Turbomachines for Energy Recovery in Water Distribution Networks
Scientific Discipline Sector	ING-IND/09
CFU	2
Year	First
Summary / Goal	Water Distribution Networks (WDNs) represent a noteworthy field for possible implementation of Small Hydropower (SHP). Indeed, WDNs experience considerable water leakages due to their age and water management authorities often divide the WDNs by inserting Pressure Reducing Valves (PRVs), which waste a potentially recoverable hydraulic head. The replacement of PRVs with turbomachines can be considered as an economically feasible solution to achieve both an effective pressure control and an energy recovery, otherwise wasted. In this framework, the course aims to provide criteria for selecting and predicting the performance of hydraulic turbomachines for energy recovery in water distribution networks. The course starts with an overview on the global scenario of renewable energy sources. In particular, hydropower sector will be deepened ranging from the large hydropower to the small/mini hydropower and its potential. Then, the available technologies to exploit hydraulic energy in water distribution networks will be illustrated (i.e., Pumps as Turbines (PaTs), Cross-flow turbines, Energy harvesting valves, etc.). Afterwards, PaTs will be investigated. After the analysis of the state of the art, the course will present performance prediction models (both theoretical and empirical). Cross-flow turbines and energy harvesting valves will be discussed in terms of performance curves and regulation techniques. Subsequently, the course will focus on methods for the selection of the proper machine for a specific WDN. Then, different case studies will be analyzed in terms of energy production and economic feasibility. The last part of the course will be focused on how to experimentally investigate a Pump as Turbine. In particular, the hydraulic turbomachinery lab (PoliBa) will be described. Then, the experimental characterization of a PaT selected for a WDN will be illustrated.

DRIME

Course title	Hydrogen for Sustainable Transportation Systems
Scientific Discipline Sector	ING-IND/08
CFU	2
Year	First
Summary / Goal	Hydrogen can play a significant role in the decarbonization process of hard-to-abate transport sectors such as heavy and long-distance road transport and maritime mobility, where electrical transportation is not technically viable. Hydrogen may be used either to feed fuel cells (FCs) or burned inside ICE. The current state hydrogen FC technology is expensive and requires pure hydrogen. Furthermore, large batteries are needed to cope with the transient nature of power demands for vehicle applications, reducing the overall efficiency. ICEs can be fueled with non-purified hydrogen, resulting in significantly lower production cost of hydrogen fuel. Furthermore, they can take advantage of the existing advanced combustion and engine control technologies. The course proposes an overview of both technologies, considering their pros and cons. The course delves into the aspects related to the configuration of propulsion systems, power management systems, storage systems, as well as the problems of deterioration of fuel cells and hydrogen embrittlement.

DRIME

Course title	Offshore Wind Technologies
SSD	ING-IND/08
CFU	2
Year	First
Summary / Goal	Offshore wind energy has the potential to integrate a large part of the renewable electric energy that will be produced in the coming years to meet the objectives of reducing global CO2 emissions. For Italy in particular, interest is focused on floating turbine technologies, which can play an important role in industrial development, with the integration of blue economy activities in ports and at sea. However, floating wind turbines still require fundamental research on platforms, turbines and mooring technologies to make them fully competitive for use in the Mediterranean, where wind speeds and sea states are lower than in northern Europe. The course provides an overview of floating turbine technologies, considering their advantages and disadvantages and their possible integration with other offshore power generation systems such as wave energy converters and floating photovoltaic platforms. The course covers aspects related to digital tools for identifying areas suitable for the development of marine renewable energy sources, tools for performance analysis and simulation, ranging from simplified models based on BEM to more accurate CFD simulations.

DRIME

Course title	OPTIMIZATION THEORY
Scientific Discipline Sector	MAT/05
CFU	2
Year	First
SUMMARY /GOAL	Mathematical Formulation. Control of production and consumption. Reproductive strategies in Social Insects. Pendulum. Moon lander. Rocket railroad car. Controllability of Linear Systems. Observability. Bang-Bang Principle. Time Optimal Control. Calculus of Variations and Hamiltonian Dynamics. Pontryagin Maximum Principle. Control of production and consumption. Linear Quadratic Regulator. Maximum Principle with transversality conditions. Distance between two sets. Commodity trading. Hamilton-Jacobi-Bellmann equation. Dynamic programming. Connections between dynamic programming and the Pontryagin Maximum Principle. Differential games. Isaacs equations. Games and the Pontryagin Maximum Principle. War of attrition and attack.

DRIME

Course title	CONSERVATION LAWS IN CONTINUUM MECHANICS AND TRAFFIC MODELING
Scientific Discipline Sector	MAT/05
CFU	2
Year	First
SUMMARY /GOAL	Euler and Burgers equations. The Method of Characteristics. Shock waves. Rankine-Hugoniot conditions. Entropy weak solutions. Oleinik Estimate. Riemann Problem. Vanishing Viscosity. Viscous shock waves. Convergence and error estimate. Legendre Trasform. Lax-Oleinik Formula. Fluidodynamic models for vehicular traffic. LWR model: shock and rarefaction waves. Moving bottleneck. Nonlocal models. Aw-Rascle model. Two phase models. Multi-population models. Traffic on networks: shocks generated by the junctions. Nonlinear elasticity. Gas dynamics. The p-system. Shock waves. Riemann invariants.

DRIME

Course title	Introduction to fluid-structure interaction
Scientific Discipline Sector	ING- IND/06
CFU	2
Year	First
SUMMARY /GOAL	The objective of this course is to deliver the key topics concerning Fluid-Structure Interaction (FSI) problems for biophysical and engineering applications. The students are expected to understand the mechanisms underlying the fluid-elastic effects in microscopic and human-scale applications, with the respective modelling approaches. The course will focus on simplified, low-dimensional models containing key aspects of real-world problems. Reference applications include bacterial locomotion, aeroelastic phenomena on airfoils, flow-induced vibrations of bridge decks, vibrations of conveying pipes. Numerical solutions will be addressed by means of a Matlab implementation.

DRIME

Course title	Contact Mechanics
Scientific Discipline Sector	ING-IND/13
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to introduce the fundamental concepts of antenna technologies for new generation telecommunication systems with a particular focus on beam steering and beam forming. The course includes the study of numerical methods and laboratory experiences for testing and characterizing antennas and antenna arrays.

DRIME

Course title	Numerical Approaches to Solid and Applied Mechanics: Boundary Element Methods (BEM)
Scientific Discipline Sector	ING- IND/13
CFU	2
Year	Second
SUMMARY /GOAL	**Theory of BEM (6 hours).** Linearity and superposition principle: integral formulation of mechanical problems. Green's function. Translation Invariance. Solution schemes of the integral convolution: Fourier vs Real space. Adaptive mesh. **BEM Applications: Contact Mechanics (6 hours)**. BE methods for contact mechanics: formulation for linear elastic and viscoelastic materials, role of the geometric domain (smooth and rough contacts), meshing and solution schemes. Boundary Element (BE) vs Finite Element (FE) methodologies: advantages and drawbacks. **Coupling BEM And Other Numerical Methods (4 hours).** Numerical coupling to study finite domains: BEM and FEM; BEM and molecular dynamics (MD). The case of soft lubrication: coupling BEM and finite difference (FD). **BEM Applications: Structural Mechanics (4 hours)**. BEM for modal analysis including fluid-structure interaction: the test case of the modal analysis for a beam immersed in a viscous fluid.

DRIME

Course title	Design of User Experience to exploit Extended Reality for the enhancement of research activities
Scientific Discipline Sector	ING- IND/15
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide PhD students with the fundamental knowledge of all these technologies, presenting both opportunities and threats. The course will start with the presentation of success stories about the use of XR in industrial research. Then, during the course, the main theoretical and methodological issues in the design of an XR application will be covered. Great relevance will be given to the practice: PhD students will be provided with tools to design User Experiences to exploit XR for the enhancement of their research activities. They will also be introduced to the use of the software Unity, a game engine commonly used to develop XR scenes. Finally, the course will teach how to evaluate the XR applications designed and developed.

DRIME

Course title	Non-Destructive (NDT): Process, Types and Applications in Mechanical Engineering
Scientific Discipline Sector	ING- IND/14
CFU	2
Year	Second
SUMMARY /GOAL	The course aims to provide PhD students the basic principles of main methods of Non-Destructive Testing for structural diagnostics. PhD students will develop skills related to the use of techniques such as penetrant tests, eddy currents, magnetic particles, thermography, and ultrasound. The lab activities will be focused on Active and Passive Thermography techniques: Pulsed thermography, Lock-in Thermography, Step Heating thermography and Thermoelastic Stress Analysis.

DRIME

Course title	Digital Manufacturing for Biomedical Applications
Scientific Discipline Sector	ING- IND/16
CFU	2
Year	Second
SUMMARY /GOAL	The program introduces digital manufacturing with a focus on biomedical applications. It covers the basics of 3D printing technologies, materials, and processes specific to the biomedical field. The program also includes a practical component where students will work on a small project, applying what they have learned. The final assessment will concern the participation in class discussions and activities and the evaluation of the small project.

DRIME

Course title	Manufacturing modeling and simulation
Scientific Discipline Sector	ING- IND/16
CFU	2
Year	Second
SUMMARY /GOAL	This program provides a comprehensive introduction to manufacturing modeling and simulation. It covers the definition and importance of modeling, various modeling techniques, the role of data, and the interpretation of simulation outputs. The course also includes case studies and a hands-on project to apply the learned concepts. The final assessment will concern the participation in class discussions and activities and the evaluation of the hands-on project.

DRIME

Course title	Adjoint methods for gradient-based optimisation and control of energy systems
Scientific Discipline Sector	ING- IND/08
CFU	2
Year	Second
SUMMARY /GOAL	The course then aims at providing PhD students with the fundamental knowledge and the main techniques for the optimization and control of energy systems using adjoint methods. Adjoint methods are powerful mathematical tools that play a crucial role in sensitivity analysis, gradient computation, and optimization of complex systems. In this course, we will focus on their application in energy systems, covering both theoretical foundations and practical implementation. The student will understand the fundamentals of adjoint methods and their relevance to optimization and control. He will be able to apply adjoint methods to: (a) perform sensitivity analyses on linear and nonlinear partial differential equation; (b) explore optimization techniques using adjoint methods for energy system design and control; (c) gain hands-on experience in implementing adjoint methods through practical examples and exercises; (d) investigate real-world applications of adjoint methods in propulsion systems, power systems, and other energy domains. Syllabus: 1. Introduction to adjoint methods a. Importance in optimization and control b. Historical context and development c. Mathematical Foundations 2. Review of calculus and differential equations a. Introduction to variational calculus b. Linear algebra and optimization concepts c. Sensitivity Analysis 3. Computing gradients using adjoint methods a. Numerical aspects and implementation b. Gradient-based optimization algorithms 4. Formulation of optimization problems in energy systems a. Constrained and unconstrained optimization b. Case studies in energy systems 5. Introduction to control theory a. Optimal control using adjoint methods b. Feedback control and stability analysis 6. Hands-on exercises with MATLAB a. Implementation of adjoint methods b. Simulation and analysis of real-world energy systems 7. Automatic differentiation and adjoint methods

DRIME

Course title	Introduction to Partial Differential Equations and Applications
Scientific Discipline Sector	MAT/05
CFU	2
Year	First
SUMMARY /GOAL	Aim of this course is the introduction to the study of partial differential equations. The three main types of linear second order partial differential equations will be considered: parabolic (diffusion equation), elliptic (Laplace equation), and hyperbolic (wave equation), underling their theoretical and applied features.

Course title	Gender studies
Scientific Discipline Sector	ING-IND/35
CFU	2
Year	First
SUMMARY /GOAL	The course aims to provide students with the theoretical and operational tools to understand the concept of gender in its historical evolution and in its social, political and economic implications. At the end of the course the students and teachers will have acquired knowledge regarding feminist theories, women's studies, men's and masculinity studies relating to the social construction of male and female identities, and will be able to identify and critically analyse the different factors that contribute to generate any inequality and discrimination based on gender.