ELENCO DEI CORSI EROGATI DALLA SCUOLA DI DOTTORATO DEL POLITECNICO DI BARI PER IL XXXVII CICLO (A.A. 2021-2022)

Il Consiglio della Scuola all'unanimità ha deliberato di erogare 46 corsi per l'A. A. 2021-2022 (per un totale di 96 CFU) in base alle seguenti proposte: 10 corsi (20 CFU) sono proposti dal DRIEI; 5 (12 CFU) corsi sono proposti dal DRSATE; 7 (18 CFU) corsi sono proposti dal DRiCIPP; 10 (20 CFU) corsi sono proposti dal DRIMeG; 7 (14 CFU) corsi sono proposti dal DRISA; 7 (12 CFU) corsi sono proposti dal DRI4.0.

L'elenco dei corsi erogati nell'A. A. 2021-2022, è il seguente:

1. Fundamentals of Information Theory, 2 CFU, SSD: ING-INF/03

Syllabus:
Definition and measures of Information
Entropy concept
Mutual and conditional information
Shannon Theorem
Channel capacity with gaussian noise
Example of source coding
Application of Information theory to security concepts

2. Video Compression, 2 CFU, SSD: ING-INF/03

Syllabus:
Video signal coding. MPEG and H.264/H.265 compression techniques.
CODEC model. Macroblocks and slices. Temporal model. Spatial model. Entropy encoder.
Temporal model. Motion estimation and compensation. Motion vectors.
Spatial model. Discrete Cosine Transform (DCT). Quantization. Rescaling and Inverse Quantization.
Overview of H.261, H.263, H.264 standards.
Overview on video applications in Internet.

3. Emerging technologies and methodologies for the Cyber Security, 2 CFU, SSD: ING-INF/03

Syllabus:
- Baseline approaches to security in current communication technologies
  - Overview of widely used communication technologies and related security services/frameworks
- Emerging encryption, authorization, and authentication mechanisms
  - OAuth 2.0 framework
  - Access control mechanisms based on IBAC, RBAC, and ABAC
  - Attribute Based Encryption (ABE) and its extensions
  - Suitable mechanisms for distributed and multi-authority environments (i.e., the symbIoTe security framework, DMA-CP-ABE)
- Security approaches for IoT, Edge, and cloud-based Cyber-Physical Systems (CPS)
  - Lightweight cryptography and key management scheme for the Internet of Things
  - Elliptic Curve Qu-Vanstone (ECQV) algorithm and Implicit X.509 certificates
  - Edge-driven security methodologies
  - Security in the cloud: goals, challenges, emerging solutions, the H2020 GUARD use case
- Blockchain and Smart Contracts
  - Reference applications
  - Emerging platforms

4. Devices and systems for satellites, 2 CFU, SSD: ING-INF/01

Syllabus:
Introduction to the Space environment
Electronic Systems for Satellite Platforms
Electronic Systems for Telecom and EO Payloads
Degradation phenomena in electronic systems due to the space environment

5. Supervision and monitoring of renewable energy systems, 2 CFU, SSD: ING-IND/31

Syllabus:
Supervision and monitoring systems for RES
Statistical tools for performance analysis of RES
Infrared analysis for the detection of faults/anomalies of RES
Software for the diagnosis of faults/anomalies - DISS

6. Green photonics for a sustainable economy, 2 CFU, SSD: ING-INF/02

Syllabus:
Introduction to green photonics.
Introduction to numerical simulation of photonic devices
Sustainable energy generation: nanostructures for photovoltaics.
Photonic devices for reduced energy consumption.
Photonic sensors for environmental monitoring.

7. Non-integer order systems and controllers, 2 CFU, SSD: ING-INF/04

Syllabus:
Introduction to fractional calculus and non-integer-order (fractional-order) systems
Modeling and identification of non-integer-order systems
Models for automotive and mechatronic applications
Non-integer-order (fractional-order) controllers: types, design, tuning, realization, fundamental properties, simulation, experimental validation
Non-integer-order (fractional-order) controllers for industrial, automotive, mechatronic and robotic applications

8. Innovative Models, Optimization Strategies and Services for Smart Building and Smart Mobility systems, 2 CFU, SSD: ING-INF/04

Syllabus:
The course includes the following main sections:
1) Introduction to Smart Buildings: definition, requirements and main challenges.
2) Innovative optimization and control techniques for Smart Buildings based on centralized and distributed approaches.
3) Modeling and simulation by MATLAB and SIMULINK of electric loads/systems in Smart Homes and Buildings.
4) Introduction to Smart Mobility: definition, requirements and main actors and challenges.
5) Innovative models and approaches based on optimization and virtual sensors for innovative mobility systems and services.

9. New Technologies For Diagnosis In Medicine, 2 CFU, SSD: ING-INF/05-MED/11

Syllabus:
- Introduzione
- Sistemi cyberfisici per la raccolta e l'analisi automatica di biosegnali. Approcci basati sull'elaborazione numerica dei segnali e sul machine learning.

- Principi di ecografia. Fisica degli ultrasuoni, armoniche tissutali, effetto Doppler. Hardware e Software di acquisizione. Software di ricostruzione in ambito cardiovascolare. Tecniche 3D. Esempi applicativi.
- Principi di risonanza magnetica. Hardware. Principi di formazione delle immagini. Sequenze impiegate in ambito cardiovascolare. Nuove tecniche ed esempi applicativi.
- Principi di acquisizione di immagine in TC.
- TC cardiovascolare: piattaforme e ricostruzione d'immagine.
- TC cardiaca: display contemporaneo di data imaging clinico, analisi e quantificazione.

10. MATLAB Recipes For Measurements Data Processing, 2 CFU, SSD: ING-INF/07

Syllabus:

Introduction: TOMFL (Test of MATLAB as a Foreign Language)
How to synthesize test signals with given spectral characteristics in MATLAB.
How to generate synthesized signals with an arbitrary waveform generator.
How to acquire signals with Data Acquisition hardware.
How to process acquired signals in the time and frequency domain to obtain selected measurements (frequency response functions, distortion, noise, etc.).

11. Advanced Probabilistic Methods For The Reliability (Performance-Based) Analysis In Engineering Problems, 2 CFU, SSD: ICAR/09

Syllabus:

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 (4 hours). 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). Finally, the concepts and applications learned in the first two parts will be the starting point for developing application problems in different fields of civil engineering (e.g. Transportation Engineering, Water Resources, Environmental Engineering, Geotechnical Engineering, …), according to the interests of the PhD students (8 hours).

12. Lab-and-field data acquisition and processes in Hydraulics, 3 CFU, SSD: ICAR/01.

Syllabus:

Goal. The course provides the basic concepts necessary to carry out measurements, process data and derive hydrodynamic and physical meanings form large data sets.
Program. 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.

13. Statistical data analysis starting from the highway engineering case, 2 CFU, SSD: ICAR/04.
Syllabus:
Motivation. Each field of research in engineering may potentially need exploratory and statistical analyses on large dataset of different nature. Highways as a part of the transportation systems generate large volume of data (such as infrastructure, traffic and accident data) which are important for several applications, primarily for safety reasons.
Goal. To provide a general theoretical background and operational methodologies (use of open-source software applications) for exploratory and statistical analyses on database, by using case studies and example problems from the highway engineering research. Program. The lectures will be organized by explaining general methodologies for data analyses starting from examples of dataset from the highway engineering. The methodologies covered are: Exploratory analyses of dataset, Tests of differences between groups (parametric vs non-parametric), Regression modelling (considering calibration). Even based on infrastructure, traffic and accident data, the transferability of the presented methodologies to other fields will be stressed, to ensure the usefulness of the course at a multidisciplinary level. Moreover, basic knowledge in using the open-source statistical software “R” may be of interest for all research fields. Verification. Based on a report explaining the development of a model or the application of statistical tests on sample of data (virtual or real) which are relevant to the individual research of each student, by means of the explained methodologies.

14. Advances in Geomatic Engineering, 3 CFU, SSD: ICAR/06.
Syllabus:
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.

15. New Frontiers Of Scientific Research Based On 3d Printing In Structural And Building Engineering, 2 CFU, SSD: ICAR/09 – ICAR10.

Syllabus:
The application of 3D printing in Structural, Building Engineering and Mechanics of Materials (e.g. 3D printing of buildings or materials with micro-structure) are becoming increasingly important in the last few years. This course aims at introducing students to the new frontiers of scientific research based on 3D printing technologies.
Firstly, the teaching program will provide an overview of the actual framework of the use of the 3D printing technology in the field of structural and building engineering. State of the art techniques, pilot projects and innovative applications will be sowed in order to point out the potential of the technology.
Secondly, various 3D printing machines will be introduced with a particular focus on the best choice of technology and printable material for specific research objectives.
Thirdly, a specific research project (which includes the use of 3D printing) will be developed by the PhD students on a topic regarding their personal research. The project can concern the realization of prototypes or the development of new methodologies for the use of the technology.

16. Theories and methods of design for the Antique, 2.5 CFU, SSD: ICAR/14.

Syllabus:
The course is divided into two parts, corresponding to the two blocks of lessons and exercises.
The first part (20 hours, 2 ECTS) 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 (10 hours, 1 ECTS) 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.

17. Theory of Contemporary Architectural Research, 2.5 CFU, SSD: ICAR/14.

Syllabus:
It seems lost today, in architecture as generally in arts, an 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.

18. Theories and Methods of the Project for the City, 2.5 CFU, SSD: ICAR/14.

Syllabus:
The course is divided into two parts, corresponding to the phases of lessons and exercises.
The first part of the course (20 hours, 2 credits) will deal with issues related to the city as a historical- aesthetic palimpsest, interpreted as a synthesis of an approach that is both documentary and transformative, based on the relationship between physical form and "cognitive form".
The second part (10 hours, 1 credit) will instead focus on issues relating to the processes and methods of urban interpretation and modification throughout history, focusing especially on those that have appeared since the twentieth century, with their multiple problems.
In this sense, various themes will be central, such as that of the "diachronic relationship" within the general urban processes, the theme of the narrative function of their inheritance, and finally the theme of the consequent theoretical and methodological choices, developed -in different ways- in the main researches of Italian and international contemporaneity (from the "organic vision" proposed by the first Roman and then Muratorian schools, to the phenomenological-cognitivist one proposed by the various Italian and American schools already in the second half of the 1900s, to the analytical- structuralist research of the successive neo-rationalist tendencies, up to the most recent ones, which experience the "dialectical contradiction" as a tool through which to reformulate the figurative heritage in relation to the unprecedented condition of the contemporary city).
This phase will be carried out through an intensive urban design workshop, based on the critical exercise of the main themes developed during the course.

19. Theories and Methods of the Project for the Territory, 2.5 CFU, SSD: ICAR/21.

Syllabus:
The course is divided into 2 steps, corresponding to the 2 blocks of lessons and exercises.
The firs tstep (20 hours, 2 ECTS) will be structured in 4 thematic sections: the first will deal with general questions on the main approaches to the contemporary territories regarding a discipline that is found between the epistemological model of scientific disciplines and that of Social Sciences; the other 3 lessons will focus on the topics that are at the heart of the contemporary disciplinary debate (as well as in the PhD course in "Project for Heritage: Knowledge and Innovation”), relating to the relationship between" City and Landscape "and" Architecture and Heritage ".
The second step (10 hours, 1 ECTS) will be dedicated to exercises and seminars of teachers external to the course: the first will be conducted in the form of a workshop on sample territories on which to experiment an approach to contemporary issues (relationship between places and communities, territories palimpsest, territories in crisis…), developing a synthetic written-graphic report concerning the main topics of the course. A seminar held by an Italian or foreign external personality, with a relevant point of view on the topics of the course, will allow a wide reflection between PhD students and author on the topics covered.

20. Theories and methods in structural design: modeling and experimental issues, 3 CFU, SSD: ICAR/08 – ICAR/09

Syllabus:
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).

21. The post-growth paradigm in planning research, 2.5 CFU, SSD: ICAR/21
Syllabus:
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 (12.5 hours) 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 (12.5 hours) 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.

22. Problems and methods of contemporary restoration, 2.5 CFU, SSD: ICAR/19
Syllabus:
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 postwar 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 (12.5 hours) 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 (12.5 hours) 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.

23. Wave energy conversion for green power generation, 2 CFU, SSD: ING-IND/08.

Syllabus:
The course starts with an analysis of the global energy scenario and the new trends towards the use of renewable energy sources in order to reduce steeply the energy-related CO2 emissions, achieving the Paris Agreement goals.Among the variety of renewables, the course will introduce the different kinds of marine energy sources: waves, tidal, currents, salinity, OTEC (Ocean Thermal Energy Conversion) (2h).

Then the course will be focused on wave energy and wave energy converters (WECs). Concerning the wave energy resource, the course will give elements of wave mechanics in order to enable a correct evaluation of the wave energy potential and some basic relations in the theory of the sea states (3h). Successively, a summary of the state of knowledge on the processes and technologies of wave energy recovery will be carried out with a special focus on Oscillating Water Column devices (2h). The OWC devices embed self-rectifying turbines in order to convert the oscillating flow, generated by the waves, into a unidirectional torque of either an impulse or a Wells turbine. The operating principles of these turbines will be described in detail(3h).

The second part of this course will be devoted to the description of the experimental (4h) and numerical (6h) approaches used to characterize these complex systems and define their design criteria. Concerning the experimental activity, the focus will be on the analysis of two rigs: (a) the small-scale plant installed in the Strait of Messina and (b) the wind tunnel devoted to the characterization of the Wells turbines. Concerning the numerical activity, the entire methodology, from the periodic wave generation (with different periods and amplitudes) up to the turbine power output, will be detailed.

24. Nonlinear Identification of Vibrating Mechanical Systems, 2 CFU, SSD: ING-IND/13.

Syllabus:
Introduction to free and forced nonlinear oscillators, coupled conservative oscillators, coupled limit cycle oscillators. Input-Output modal analysis of nonlinear systems. Nonlinearity in the measurement chain. Means of indicating nonlinearity. Frequency response functions (FRFs) of nonlinear systems. Harmonic balance. Inverse FRFs. Frequency-domain Nonlinear Subspace Identification (FNSI).

25. Mechanical Characterization of Materials by Advanced Ultrasonic Tests, 2 CFU, SSD: ING-IND/14-ICAR/08.

Syllabus:
Fundamentals of Non-Destructive Tests. The Ultrasonic Tests: Theory and Application. Theory: Linear Elastodynamics theory; Ultrasonic wave propagation in anisotropic materials; Ultrasonic wave propagation in prestressed materials (the study of the acoustoelastic effect). Application: Linear Ultrasonic methods for the mechanical characterization of materials; Non-Linear Ultrasonic methods for the evaluation of damage of materials (fatigue damage; stress induced damage; etc.). Experimental applications: Ultrasonic contact tests; ultrasonic immersion tests (ultrasonic goniometric immersion tests and ultrasonic C-Scan); Laser ultrasonic tests.

26. Dynamical behavior of nonlinear structures, 2 CFU, SSD: ING-IND/14.

Syllabus:

1.Free vibration of dynamical systems with nonlinear stiffness1.1.Physical systems described by the Duffing equation: pendulum, mechanical isolators, nonlinear beams, electrical circuits1.2.Fixed points, phase portraits for softening and hardening nonlinearity1.3.Numerical integration of the free Duffing's equation 2.Forced vibration of dynamical systems with nonlinear stiffness2.1.Approximate solutions for forced oscillations of the Duffing equation2.2.Numerical Integration of the forced Duffing's equation 2.3.Qualitative analysis of timeseries: Recurrence Plots, Poincarè Section, Bifurcation diagram, FFT analysis 3.Vibration of dynamical systems with nonlinear damping3.1.Self-excited vibration of systems with nonlinear polynomial damping (Time integration example, phase portrait) 3.2.Approximate harmonic balance solution4.Numerical Continuation of equilibrium solutions1.1.Sequential Continuation, Davidenko-Newton-Raphson Continuation, Arclength Continuation, Pseudo-Arclength Continuation 5.Vibration Localization in linear and nonlinear systems1.Friction-excited systems2.Externally excited systems3.Multiplicity of solutions with regular/irregular behavior4.Localized states and propagating fronts in a weakly coupled oscillators.

27. Mixed Reality for data visualization in the Smart Factory, 2 CFU, SSD: ING-IND/15.

Syllabus:

The course then aims at providing PhD students with the fundamental knowledge of MR, presenting both opportunities and threats. The course will start with the presentation of success stories about the use of MR in industrial research. Then, during the course, the main theorical and methodological issues in the development of an MR application will be covered: (i) the displays used to visualize information in MR; (ii) the registration of the virtual world within the real world; (iii) the interaction between the user and the application. Presenting these issues, the main differences between AR and VR will be discovered.

Great relevance will be given to the practice: PhD students will be introduced to the use of the software Unity 3D, a game engine commonly used to create MR scenes. During these technical laboratories, some MR samples will be created step-by-step.

28. Multidisciplinary Research Applications of 3D Printing, 2 CFU, SSD: ING-IND/16.

Syllabus:

1. 3D Printing processes and materials according to ISO/ASTM 52900
2. Latest research applications of filament extrusion and polymerization processes
    a. 3D printed microfluidics
    b. 3D printed sensors
    c. 3D printed actuators
3. Latest research applications of metal powder processes

29. Implementation and application of Design of Experiment techniques to experimental and numerical campaign, 2 CFU, SSD: ING-IND/14.

Syllabus:

1. Review of main statistical tools related to Design of Experiment (4 hours)
    a. Descriptive statistics
    b. Inferential statistic
    c. Test of hypothesis
    d. ANOVA

2. Factorial design (4 hours)
    a. One variable
    b. 2 variables without and with replication

c. Multi parameters
3. SRM surface response methodology (2 hours)
4. Study cases (8 hours)
a. Experimental setup and analysis
b. Application in Machine Design
c. DOE for numerical simulations
5. Guided implementation of an individual study case

30. Sustainability in smart manufacturing: open research questions, 2 CFU, SSD: ING-IND/16.
Syllabus:
Introduction to sustainability issues
Open research issues:
Energy and energy storage
Manufacturing processes and technologies
Smart production and sustainable performance

31. Human-based Smart Manufacturing Systems, 2 CFU, SSD: ING-IND/17.
Syllabus:
Industry 4.0. Human Factors in Industry 4.0. Enabling technologies. Industrial visit.

32. Collective intelligence of human groups, 2 CFU, SSD: ING-IND/35.
Syllabus:
-Origin and definitions
- Building blocks
- Drivers
- Statistical physics of collective decision making
- Discrete and continuous models
- Phase Transition, Criticality and the Emergence of Swarm intelligence

33. High-energy particle physics detectors in space, 2 CFU, SSD: FIS/01.
Syllabus:
Basic elements of particle physics. Interaction of charged particles and photons with matter. Generalities on astroparticle physics. Detectors for space applications: scintillators, photon detectors, silicon detectors.
Environmental verification strategy for space detectors: qualification and acceptance. Structural and mechanical verification requirements. Sinusoidal sweep vibration test, random vibration test, acoustic tests, mechanical shock tests. Electromagnetic compatibility requirements. Vacuum, thermal and humidity verification requirements. Thermal balance, thermal vacuum, temperature-humidity verification.

34. Oscillations and waves, 2 CFU, SSD: FIS/01.
Syllabus:
Generalities on oscillations and mechanical waves. Longitudinal waves and transverse waves. Wave propagation. Examples of acoustic waves and acoustic beats. Doppler effect and shock waves. From Maxwell equations to electromagnetic waves. Polarization of electromagnetic waves. Energy propagation in the electromagnetic waves: Poyinting vector. Radiation pressure. The electromagnetic spectrum. Generalities on interference and diffraction.

35. Spacecraft Structural Dynamics & Loads, 2 CFU, SSD: ING-IND/04.
Syllabus:

• Structural dynamics (4 hours): Overview about structural dynamics and its importance in the development of the spacecraft structures (design, analysis & test).
• Dynamics and loads (4 hours): Introduction to the "logic and criteria" of the design and tests as regards "dynamics and loads".
• Basic concepts (4 hours): Introduction of some important topics such as "modal effective mass", "dynamic testing" and "model validation".
• Experimental results (4 hours): Results of some applications (satellites, launchers, etc.).
• Numerical methods (4 hours): Presentation of structural dynamics analyses (and specifically of some numerical methods).

36. Hypersonic Gas Dynamics and CFD, 2 CFU, SSD: ING-IND/06.

Syllabus:
(4h) Introduction to hypersonic flows and short review of basic gas dynamics: definition of hypersonic flow; Knudsen number, flow regimes and governing equations; quasi-one-dimensional flow, area Mach number relation, normal shock waves, oblique shock and expansion waves.
(8h) Properties of high-temperature gases: microscopic description of gases, Boltzmann distribution, thermal and chemical non-equilibrium: classical multi-temperature model and introduction to State-to-State approaches;
(3h) Gas dynamics of high-temperature flows: quasi-one-dimensional flow, normal shock waves, speed of sound, oblique shock and expansion waves.
(3h) Gas surface interactions: catalytic and ablation phenomena.
(2h) Overview of Computational Fluid Dynamics approaches for hypersonic flows and numerical examples.

37. Hydrogen combustion challenges for renewable power generation and aero-engines, 2 CFU, SSD: ING-IND/06-ING-IND/08.

Syllabus:
1. Towards a low-carbon combustion: motivations and challenges
2. High-fidelity simulations of reactive flows: an overview of turbulent combustion modelling for premixed and diffusion flames and challenges of hydrogen addition.
3. Impact of hydrogen addition on steady flames: flame structure, emissions and wall-heat transfer.
4. Unsteady combustion dynamics: flashback.
5. Unsteady combustion dynamics: Intrinsic and thermoacoustic combustion instabilities.
6. Safety problems linked to hydrogen: auto-ignition of fuel leaks and deflagration to detonation transition (DDT).
7. An overview of current research and technical solutions for low-carbon combustion in land-based gas turbines and aero-engines.

38. Optical communications for space, 2 CFU, SSD: ING-INF/02.

Syllabus:
- Introduction to optical space communication
- Optical Links and Satellite communication
- Metasufaces and periodic structures for beam steering and energy harvesting/generation.
- LIDAR principles.
- Principles of the Quantum Key Distribution.

39. Time-series databases for sensor data analysis, 2 CFU, SSD: ING-INF/05.

Syllabus:
1. Time-series databases [4h]
    a. Features of time-series data: variability, seasonality, stationarity, autocorrelation;
    b. Time-series modeling approach: structured data, data stream;

c. Basic geospatial data types;
d. Time-series DBMS.

2. Processing time-series data [10h]
   a. Data visualization and monitoring solutions;
   b. Predictive analytics for sensor data.
3. Using a time-series database [6h]
   a. Collecting data from sensors and systems;
   b. Querying time series data;
   c. Visualizing and managing time series data;
   d. Processing, analyzing and acting on time series data in real time.

40. Advanced Materials for Sensing Technologies, 1 CFU, SSD: CHIM/01.
Syllabus:
Nanomaterials: basic principles and properties
Nanomaterials and interfaces: characterization techniques (Electron Microscopies & Spectroscopic techniques)
Sensor devices: basic principles
Nanomaterials for sensor development
Examples of smart sensors

41. Complex Networks: Big Data modelling and learning, 2 CFU, SSD: FIS/07.
Syllabus:
- Introduction: graph theory.
- Different graph models.
- Nodal and edge characterization.
- Local and global properties.
- Community detection.
- Learning: Basic definitions, bias, variance and cross-validation.
- Supervised Models.
- Deep Learning.
- Unsupervised models: Clustering.
  The use of computational facilities.

42. Flexible and Stretchable Electronics, 2 CFU, SSD: ING-INF/01.
Syllabus:
General introduction to flexible/stretchable electronics
Microcontroller-based electronic systems
Flexible sensors and actuators
Lab-on-skin technology
Flexible and stretchable devices for human-machine interfaces
Electronic Textiles

43. Innovative Materials for Energy Conversion Technologies, 1 CFU, SSD: CHIM/03.
Syllabus:
Introduction to Materials Chemistry
Emerging Photovoltaics
Halide Perovskite Based PV

44. Photonics for Industry 4.0, 2 CFU, SSD: ING-INF/02.
Syllabus:
- Introduction to Photonic applications in Industry 4.0.

- Light-based advanced manufacturing, Material welding and material treatments for Laser Additive and Subtractive advanced fabrication.
- Light Detection and ranging principles, LIDAR technologies for autonomous vehicles
- Optical wireless communication for low latency and high-performance data transmission. High-Speed Optical Wireless technologies, LiFi, hybrid wired/wireless technologies.

45. Physical Layer Security for wireless communication, 2 CFU, SSD: ING-INF/02.
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

46. Smart Education for Industry 4.0, 2 CFU, SSD: INF/01.
Syllabus:
1. Smart Education Fundamentals
2. Smart Learning Environments
3. Serious games
4. Gamification
5. E-learning Platforms and MOOCs (Massive Open Online Courses)