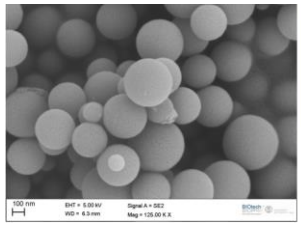
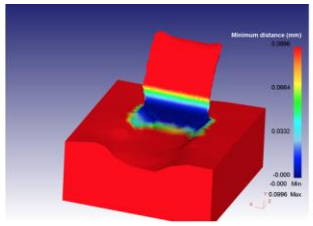
UNIVERSITY OF TRENTO

Doctoral School in Materials, Mechatronics and Systems Engineering

Doctoral Candidate Handbook


http://www.unitn.it/drmmse

Academic year 2023-2024

IMPORTANT GENERAL NOTICE

This handbook contains in a handy format most of the information regarding the Doctoral School in Materials, Mechatronics and Systems Engineering, that is in part available also on the website of the Doctoral School and of the University of Trento.
All information and provisions given in the present Handbook might undergo reviews and modifications.

Contents

Presentation

The Doctoral School

The Doctoral School in Materials, Mechatronics and Systems Engineering (MMSE) has been established by the Department of Industrial Engineering and represents the highest academic instruction level. It aims at educating professionals able to play a key role in the research, design and production fields of industrial engineering. A particular focus is given to advanced materials, mechatronics and systems engineering.

The most relevant research areas in **Materials Science and Engineering** include:

- nanostructured materials (metallic alloys, ceramic powders, inorganic systems from sol-gel and polymer nanocomposites)
- powder metallurgy
- biomaterials and biomedical technologies (also developed at the BIOtech, Center for Biomedical Technologies)
- polymeric and composite materials
- materials for energy (photovoltaic, solar thermal, fuel cells, hydrogen storage)
- materials chemistry
- high-strength glasses and ceramics
- coatings and surface treatments
- wear phenomena
- corrosion, degradation and mechanical fatigue
- experimental characterization of the mechanical behaviour of materials and numerical modeling
- atomistic modeling of materials
- microscopy (optical, confocal, electronic and atomic force)
- nuclear magnetic resonance (NMR) methods
- microstructural and micromechanics analysis through X-ray diffraction
- sustainable materials (low impact, biodegradable, from renewable resources)
- additive manufacturing

The research activities on **Mechatronics and Mechanical Systems** are based on a multidisciplinary approach reflecting the most advanced developments of the Concurrent Engineering approach. Research activities are also carried out at the ProM Facility Lab of the Mechatronics Centre in Rovereto (TN). Among the research topics, the following can be listed:

- autonomous vehicles and robots
- intelligent machine tools and machining processes
- product innovation
- modeling, simulation and control of process
- modeling and simulation of mechatronics system
- measurement systems and sensor data fusion
- accessibility and assistance systems
- modeling of the human movements
- mechanisms for space applications
- numerical analysis and SW development for dynamic simulation and optimization
- control and identification of linear, non-linear and hybrid dynamic systems
- model-based design and control of smart materials systems
- design of robotic system and components

The main research activities in the area of **Electronic Systems and Integrated Microelectronic Systems** are focused on design and development of systems for acquisition, processing and management of signals and information useful to solve problems of industrial and social relevance. Collaborations with FBK. Among the current research topics, the following can be listed:

- microelectronics and microsensors
- CMOS image sensors and radiation detectors
- embedded systems
- wireless sensor networks and cyber physical systems
- wearable computing
- intelligent systems and instrumentation for the quality of life
- systems on chip (SoC), energy harvesting and ultra-low power methodologies
- distributed measuring systems
- smart energy systems
- metrology for quality management

The main research in the area of **Operational Research** consists of the development of mathematical models to support and analyze the economical efficiency, productivity, performance, and quality of industrial processes. In particular, the activities comprise the development and use of software tools to help managers and engineers in evaluating complex contexts and reach "optimal" decisions when complete knowledge is not available, or uncertain, or contradictory. The following is a partial list of current topics of interest:

- multi-criteria decision modelling
- preference modelling
- linear and non-linear programming
- dynamic programming
- network analysis (PERT CPM)
- queuing models
- inventory models
- risk analysis
- simulation techniques
- fuzzy systems
- soft computing
- machine learning (ANN, SVM)
- project management
- project financing
- decision support systems
- learning management systems
- business analysis
- requirements engineering
- web reputation management

In each of the above-mentioned fields, and in additional related ones, it is possible to develop PhD thesis having both fundamental and/or industrial oriented approaches.

Official language: English

Duration: 3 years

Every year, an announcement is published advertising the public selection of candidates. The announcement specifies the number of openings and scholarships offered. The School is committed to enrol the most qualified students regardless of sex, age, nationality, religion, race or social status.

Location

Trento lies at 190 metres altitude in the wide glacial Adige river valley, in the heart of the natural and historical itineraries between Lake Garda and the Dolomites. It is dominated by the nearby mountains of Bondone (2.180 m.) and Paganella (2.125 m.).

It has a rich history, dating back to Roman times, and nowadays it is an important town along the Venice-Verona and Bolzano-Innsbruck route. The region around Trento is of extraordinary beauty, with its unique mountains and lakes that offer the participants many exciting outdoor activities like skiing, hiking or climbing.

The Doctorate is hosted by the Department of Industrial Engineering, in a modern building in Povo (via Sommarive 9 – 38123), where students and teachers can interact informally.

Organisation

Director of the Programme

prof. Gian-Franco Dalla Betta
tel. +39 0461 283904
e-mail: gianfranco.dallabetta@unitn.it

The Director of the Programme is elected by the School Teaching Board of the Doctoral School among the full and or associate full-time tenured professors who are members of the School Teaching Board and work at the University of Trento.
The Director is responsible of the School, steers its work and represents it.
The elected Director remains in charge for three years.
The Director:

a. co-ordinates and organizes the training and administrative work of the School;
b. calls and chairs meetings of the School Teaching Board and implements the respective resolutions;
c. authorizes Doctoral students, in agreement with the respective supervisors, to leave the university to conduct further research work or work placements at Italian or foreign universities for periods of less than six months;
d. reports to the competent Administrative Offices in cases where Doctoral students do not fulfil their obligations of the University Regulations and implements the appropriate disciplinary measures (suspension of payment of the grant or expulsion of the student from the School);
e. at the end of every academic year, redacts a detailed report on the status of the School that year, which will be submitted to the University Internal Evaluation Committee;
f. designates a Deputy-Director who will stand in for him or her in the event of illness or impediment.
g. authorizes the Doctoral student to conduct ancillary or supplementary educational activities and extra-curricular research activities.

In order to carry out the administrative duties, the Director can be aided by the Department Assistant or other personnel of the Department of Industrial Engineering (DII) Secretariat; in particular, the Assistant draws up the minutes and other documentation, handles international relations, organizes the selections and the final examinations, and handles relations with the central office.
The Assistant may be invited to participate in the meetings of the School Teaching Board without voting rights, assuming the function of secretary and taking the minutes.

Secretariat

Secretariat: Alice Aste
Tel. +39 0461 282401
e-mail: dii.phd@unitn.it

The Secretariat is responsible for the administrative management of the School. It supports the Director of the Programme and the Doctoral candidates. It is the main reference office for the School's Doctoral students.
E-mail is the primary mode of communication in the Doctorate, and all deadlines and school-related news and events will be communicated via e-mail. It is imperative that Doctoral students check their e-mail on a regular basis and keep the Secretariat updated on any changes to their e-mail address. The Director of the Programme will not approve exceptions based on not knowing regulations or deadlines.

School Teaching Board

Full Professors	• Bortoluzzi Daniele • Da Lio Mauro • Dalla Betta Gian-Franco • Deflorian Flavio • Fontanari Vigilio • Fontanelli Daniele • Marques Pereira Ricardo Alberto • Molinari Alberto • Motta Antonella • Pegoretti Alessandro • Pellizzari Massimo • Petri Dario • Quaranta Alberto • Sglavo Vincenzo Maria • Sorarù Gian Domenico • Straffelini Giovanni • Tedeschi Elisabetta • Zaccarian Luca
Associate Professors	• Anesi Alexandre • Benedetti Matteo • Bertolazzi Enrico • Biral Francesco • Bortot Silvia • Bosetti Paolo • Brunelli Davide • Brunelli Matteo • Cristofolini Ilaria • De Cecco Mariolino • Del Prete Andrea • Di Caprio Debora • Dirè Sandra
	• Dorigato Andrea • Fambri Luca • Fedel Michele • Gialanella Stefano • Giordano Giulia • Lobino Mirko • Macii David • Maniglio Devid • Menapace Cinzia • Mich Luisa • Nollo Giandomenico • Pancheri Lucio • Parrino Francesco • Pilati Francesco • Rosati Papini Gastone Pietro • Rossi Stefano • Rustighi Emiliano • Zanella Caterina
Aggregate Professors	• Biesuz Mattia • Moretti Giacomo • Rech Paolo • Saveriano Matteo • Suzic Nikola • Tirella Annalisa • Zago Marco
Experts	• Masia Marco • Pepponi Giancarlo • Rossi Barbara
Students Representatives	• Albanese Andrea • Lunardi Gianni

The School Teaching Board consists of full, associate, aggregate professors and experts. The members of the School Teaching Board are active in research, as documented by their CV. Important elements to prove this are the list of publications of the last five years and the coordination of research projects.

Representatives of the Doctoral students can take part in the meetings of the School Teaching Board when issues concerning the general performance of the School and the training courses are in the agenda. Two student representatives are elected every second year from among those enrolled in the School.

Other persons may assist, without the right to vote, in School Teaching Board meetings or discussion of specific matters if invited by the Director.

The School Teaching Board:

a. organizes the training and research activities of the School and defines its specialization programmes;
b. discusses and organizes the Handbook of studies each year, including all the courses which are part of the Manifesto and of the Syllabus;
c. supervises the progress of the training and research activity of each Doctoral student;
d. approves the individual study plans of the students at the beginning of each academic year;
e. identifies two or more Supervisors, internal or external to the School Teaching Board, for each Doctoral student;
f. approves participation of the students in training periods, work placements and research organized at Italian and foreign public bodies or private organizations if the period involved is longer than six months;
g. approves the advancement of the Doctoral student from one year to the subsequent one;
h. approves the admission of the Doctoral students to the final examination at the end of the course;
i. approves the admission of new members to the School Teaching Board;
j. can set up an Executive Committee and designates persons in charge of the specialization curricula;
k. approves the annual report drawn up by the Director;
l. submits to the Rector the names of the members of the Admission Committee to the School and of the Examination Committee;
m. promotes partnerships with other Italian and foreign universities as well as public bodies and private organizations in order to improve the research activities.

Meetings have a quorum when at least half plus one of the members of the School Teaching Board is present, minus any justified absent.
Resolutions are adopted with the favourable opinion of the majority of those presents. In the event of a tie, the Director shall have the final vote.

Registrations

ENROLLMENT IN THE 1ST YEAR.
Successful applicants have to enrol to the PhD Programme within the deadline specified in the announcement of selection.
Enrollment procedure is online at: www.unitn.it/en/apply/imdott.
TDS Education Tax for AY 2023/2024 is of € 166,00 (€ 150,00 for the tax + € 16,00 for the stamp duty) and has to be paid through the payment system called PagoPA.
Further information about the enrollment in the 1st year, such as mandatory attachments, TDS Education Tax, stay permit and withdrawal, are available at:https://www.unitn.it/en/ateneo/1928/enrolment-in-the-1st-and-following-years.

ENROLLMENT IN THE 2ND OR 3RD YEAR.
After the decision of the School Teaching Board concerning the admission to the 2nd or 3rd academic year Doctoral students are required to enrol online at: https://www5.unitn.it/Apply/en/Web/Home/imdott.
TDS Education Tax for AY 2023/2024 is of € 166,00 (€ 150,00 for the tax + € 16,00 for the stamp duty) and has to be paid through the payment system called PagoPA.

Program of studies

All students must carefully read the Internal Regulations of the PhD School available at http://www.unitn.it/drmmse/16/regulations-documents-forms, which include the following information:

Credits

To complete the whole programme, the student must obtain **180 credits** as follows:

- **40 credits** for courses and other educational activities, according to a personal study plan formulated by each Doctoral student with the assistance of the Supervisor and submitted for the approval to the School Teaching Board, which includes:

  i) at least 20 credits (corresponding to about 120 hours) (type A credits) obtained by attending institutional courses with final assessment listed in the Syllabus, or by attending specialized courses of a similar level offered by Italian or foreign university institutions. Students are advised to obtain these credits preferably by the end of the second year. A syllabus of the Courses offered by the members of the School Teaching Board is reported in the attached Doctoral Candidate Handbook. The type A didactic credits are assigned on the basis of the ECTS system and only if the student has attended at least 75% of the lectures and passed the final assessment.

  ii) a maximum of 20 credits (type B credits) obtained in other activities such as seminars, workshops, summer (or winter) schools, formative stages at public and private entities and companies and on-line courses; the School Teaching Board evaluates the suitability of such activities with respect to the training and research objectives of the Doctoral School. These credits must be obtained by the end of the third year and they must be approved by the School Teaching Board.

- **140 credits** for research on the topic of the final thesis and writing it, including research sessions spent at Italian or foreign universities or research institutions.

The courses offered by the School aim to expand the student's skills and knowledge needed to a smooth advance of his/her research activity.

Each Doctoral student must submit for the approval of the School Teaching Board, by the month of February, an individual study plan, drawn up in agreement with the Supervisor/s. If required and supported by the Supervisor some courses can be also selected among those offered by other institutions, after approval of the Teaching Board. This is particularly applicable in the case of students inserted in a co-tutelle agreement whose study plan must comply with the regulations and requirements of both the partner institutions; specific provisions may be set in the individual agreement.

Supervisor(s) appointment

The School Teaching Board will officially assign to each student one Supervisor, and at least one co-supervisor, on the basis of his/her research interests. The Supervisor is responsible for the quality assurance of the research programme. At least one among Supervisor and co-Supervisors must be a member of the School Teaching Board and he/she/they must be research-active in the relevant field.
The Supervisor will be an active researcher in the relevant aspects of the research programme, with a record of significant publications according to the criteria adopted by the University for the evaluation of the quality of the research.

The Supervisor assists the Doctoral student in the choice of the individual training programme and in choosing the topics for his/her research activity. In particular, the Supervisor should assist the student in defining her/his study plan as well as in defining the content of the thesis.

The Supervisor guides the student in his/her research activity. The primary objective is to promote the Doctoral student's gradual acquisition of autonomy in carrying out scientific research activity, written and oral presentation of the results of the research, preparation and management of parts of research projects and his/her insertion in the international scientific circuit.

The Supervisor should report to the School Teaching Board cases in which the research work does not meet the standards of the School. In addition, the Supervisor advises the student during the research activity and

ensures that her/his conduct is respectful of the regulations of the School, since they are considered fundamental for the value of the School and for scientific and professional growth of the Doctoral students.
If at any stage during the course of the programme the Supervisor has concerns about progress, he should inform the student in writing.
The School Teaching Board can remove the Supervisor from her/his responsibility whenever she/he does not fulfill her/his obligations.
The School Teaching Board may assign the Doctoral student one or more co-Supervisors, who may be external.
The co-Supervisor has the same rights and obligations as the Supervisor.

Bimonthly report

Students are required to submit a bimonthly report to the School Director describing the main activities performed in the previous two months (courses attended, progresses in the research project, preparation of manuscripts, attendance to scientific conferences, etc.).

Admission to second and third year

At the end of the first and second year each Doctoral student will give a public seminar focuses on his/her research activities. An Examination Committee comprising at least two members of the School Teaching Board will evaluate the student and will make a recommendation to the School Teaching Board for the admission to the following year.
The student is assessed on the basis of research contents and level of advancement of the same, his/her mastery of the subject and the quality of the presentation.
Other aspects that will be evaluated are his/her attendance and/or participation to scientific conferences and his/her preparation of scientific publications. In particular, for the admission to the third year, students are required to have written at least one scientific article (already published or at least submitted for publication) in international scientific journals listed in Web-of-Science, SCOPUS, or PubMED databases.
Admission to the second and third year will be decided by the School Teaching Board after examining the student research activity and expected results and by taking into account the recommendation of the above-mentioned Examination Committee.
The denial of admission to the second or third year will cause the permanent exclusion from the PhD programme and the suspension of related scholarships.
In case of a specific request by the Supervisor an "in itinere" evaluation exam can be scheduled during each year.

Admission to the final examination

By the end of the third year the student must pass an exam to be admitted to the final examination. The Supervisor will submit to the Examination Committee, comprising at least two members of the School Teaching Board, an assessment on the candidate's overall research activity and quality during the PhD programme.
Prerequisite to be admitted to the final test is the publication of at least two scientific articles (in print or accepted for publication) in international journals listed in Web-of-Science, Scopus or PubMED databases.
In the presence of at least one scientific article, the admission to the final exam could be taken in consideration and possibly accepted by the Teaching Board even in the absence of the aforementioned requirements, only if such failure is justified in written form by the Supervisor (as part of his/her assessment of the candidate) and by the student well in advance (at least 4 weeks) with respect to the date of the exam.
Students admitted to the final exam are requested to send the thesis draft to the referees, as well as a report of the activities developed during the Doctoral programme and about the publications, by January 31st of the year following the conclusion of their doctorate's cycle. For students who have benefited from a suspension, under the terms provided for by the University Regulations, the aforementioned deadline for admission to the referee procedure and the submission of the thesis must be deferred for a period equal to the duration of the suspension.
In compliance with the Ministerial Decree 226/2021 and the current University Regulations, it is introduced the possibility of an extension for a period not exceeding twelve months with respect to the regular duration of the doctoral cycle of the application for admission to the referee procedure. Candidates wishing to benefit of this extension must submit a reasoned request to the coordinator at least thirty days before the end of the last year of the course. The authorization to exceed the deadline for the submission of the thesis does not entitle to further assignments of scholarships.
Given the scientific relevance of the diffusion of research results, PhD students are encouraged to participate to international conferences with papers and oral presentations of their research findings.

Final examination

Admission to the final examination is granted by the School Teaching Board that examines the Supervisor's evaluation and expresses an appraisal for each Doctoral student. For each admitted student the School Teaching Board identifies two or more evaluators (hereinafter referred to as "referees").
The Secretariat will send to the referees:
a. copy of the thesis of the candidate, previously approved by his/her Supervisor;
b. presentation letter by the Supervisor which includes the activities carried out by the candidate during his/her Doctoral Programme;
c. report by the candidate on the activities s/he has carried out during the Programme and publications;
d. Annex A and B in which both the Supervisor and the candidate make a statement about the authorship and originality of the manuscript.
The referees will assess the thesis work with a critical evaluation and a report with comments and suggestions for improvements within 1 month from the delivery of the thesis and the related attachments.

Degree award

The Examination Committee in charge of the final exam for the award of the PhD title is appointed by the School Teaching Board or, by delegation, by the Executive Committee, in accordance with the provisions set by the University Regulations.
The thesis defence is the final exam required for awarding the PhD degree. It is held by the Examination Committee as a public exam in which the student presents his/her thesis work, defends it against possible criticisms and demonstrates his/her mastery of the subject matter on which the thesis is based.
The examination must be held within six months from the conclusion of the Doctoral programme, except in case of extension as described in the previous art. 15, par. 8. The aforementioned six-month term is extended if the deadline deriving from the postponement indicated by the referees for any further detailed revision of the thesis is not compatible with it.
If one or more of the external commissioners are prevented from physically attending the session, the Commission may gather in a videoconference meeting.

Manifesto of studies 2023/2024

Credits	Course	Teacher(s)	Period
Materials Science and Engineering			
2	Biodesign applied to tissue engineering *	Motta	March – April 2024
3(+3 lab)	Coatings for corrosion protection and electrochemical surface characterization	Deflorian, Rossi	12, 13, 16 February 2024
2	Environmental sustainability of the materials	Dorigato	20 January – 20 February 2024
2	Scanning probe microscopy – Theory and Practice	Maniglio	16, 18, 23, 25 January 2024
2	Optical properties of nanomaterials	Quaranta	11 – 22 March 2024
2	Computational thermodynamics II	Pellizzari	May 2024
2	Design and manufacturing of (nano) technologies for controlled release of biomacromolecules	Tirella	May 2024
2	Electron microscopy techniques – Theory	Gialanella	Early January 2024
2	Electron microscopy techniques – Practice	Ischia	Second half of March 2024
2	Elemental analysis by X-ray spectroscopy – Practice *	Maines, Bortolotti	
3	Friction and Wear of Materials	Straffelini	January – February 2024
3	Materials science and technology	Calovi, Fredi	4 – 15 March 2024
2	Qualification SEM and TEM *	Ischia, Maines, Motta	
2(+2 lab)	Thermal analysis	Fambri, Pellizzari	22-25 January 2024
* Courses offered on demand (contact the School Secretariat)			
Mechatronics and Mechanical Systems			
3	Mathematical epidemiology - modelling, parametrization and applications.	Giordano + Proverbio	Beginning of March 2024
2	Mechanical vibrations in spacecraft design	Bortoluzzi	January – March 2024
2	Object Detection for Automotive Applications and Space Exploration: reliability opportunities and challenges	Rech	March-May 2024
3	Saturated control systems	Zaccarian	September - October 2024
3(+3 lab)	Scientific computing	Bertolazzi	End January – beginning of February 2024
3	Simulating autonomous car dynamics with IPG CarMaker	Cherubini	15-19 January 2024
2	Vision-language-action models for robotics and autonomous vehicles	Da Lio + Plebe	March-April 2024

Electronic Systems and Integrated Microelectronic Systems			
3	Designing and programming the Internet of Things (IoT).	Brunelli D.	April-May 2024
3	Image sensors	Pancheri	End January – End March 2024
3	Silicon radiation detectors	Dalla Betta	16 January – 15 February 2024
3	The electrification behind the green revolution	Tedeschi	July 2024
Operational Research			
2	Basics of reliability engineering	Brunelli M.	June 2024
3	Project management	Molinari	July 2024
2	Simulation of production and logistics processes	Pilati	September 2024
Multidisciplinary Research Tools and Languages			
3(+ 6 project)	Multidisciplinary integrated design project	Brunelli D., Maniglio, Pancheri	
3	Virtual instruments for data acquisition and signal analysis	Macii	
2	Academic writing for science and engineering	Hope	
2	Academic writing II (sciences and engineering)	Hope	
2	Presentations for science and engineering	Hope	

All details (and changes) regarding the timetable and rooms will be published on the website at the following page: http://www.unitn.it/en/drmmse.

Courses Syllabus (description of courses)

Materials Science and Engineering

Biocompatibility of materials and sterilization methods: an introduction

Teacher: Alexandre Anesi
ECTS: 2
Content: The course aims to provide an introduction to the concepts of biocompatibility and the body's reaction to implants.
For medical devices that directly or indirectly contact patients, biocompatibility testing is required to obtain regulatory approval in most markets. The students will learn principles of biocompatibility, including medical devices, biomaterials, biological systems these devices interact with, host and material responses and biocompatibility testing.
The students are invited to apply knowledge of biological performance concepts to development of preclinical evaluation programs for medical materials and devices, in particular tissue-engineered devices that incorporate biological materials and cultured cells.
The need of biomaterial sterility will be underlined, prior to the incorporation of cells or in living tissues. How material sterilization and handling may affect device/material function will be discussed.
Subtopics:

- Biological evaluation process for a medical device
- Categorization (intended use, body location, duration of use)
- Characterizations (materials)
- Need for testing
- *In vitro* testing
- *In vivo* testing
- Developing a biological performance testing strategy according to ISO 10993 guidelines
- Applications of ISO 10993-5:2009 Biological evaluation of medical devices Part 5: Tests for in vitro cytotoxicity.
- Applications of ISO 10993-6:2016 Biological evaluation of medical devices Part 6: Tests for local effects after implantation
- Fundamentals of sterilization
- Material sterilization and handling may affect device/material function
- Selection of the most appropriate sterilization procedure, specific to the material used and its intended applications

Exam: A written report and/or a narrated 'presentation' (individual), and peer review of each other's presentations (group). Final discussion (group).

Biodesign applied to tissue engineering

Teacher: Antonella Motta
ECTS: 2
Content: The aim of the course is an introduction to a comprehensive understanding of the components involved in the interdisciplinary field of tissue engineering, as well as the inter-related nature of these components in terms of functional tissue outcomes. The students will learn principles of how to design scaffolds starting from the analysis of natural models, with consideration of cell biology, tissue architecture, macromolecules, releasing systems and their physiological relevance.
Advanced biomaterial selection and biomimetic scaffold design for tissue engineering and regenerative medicine will be discussed: definition of construct requirements, formulation of bio-inspired design criteria, selection of natural polymer sources, scaffold characterization and testing, and applications in forming complex tissues or organogenesis.
Subtopics:

- Biodesign as an innovative approach in several fields
- Strategic consideration for tissue engineering
- Extra Cellular Matrix as a model of a dynamic self-assembled construct
- ECM as a composite material
- Self assembling and self-healing mechanisms
- Role in tissue morphogenesis
- Cells and cell therapy:
- materials and cell interactions
- Natural-derived polymers:
- properties, function,
- natural sources for TE application
- Bio-Engineered scaffolds to maximize biological response: how to translate biological mechanism-information into a therapeutic construct-device:
- From biological complexity to simplicity
- Biological functions and selection of scaffold requirements
- Correlation between material/ architecture and cell/tissue type
- Scaffold characterization: biological testing, bioreactors, imaging

Exam: Written test and final discussion.

Coatings for corrosion protection and electrochemical surface characterization

Teachers: Flavio Deflorian, Stefano Rossi
ECTS: 3 + 3 (lab.)
Content: The aim of the course is to give students the basic knowledge of the coatings used to improve the corrosion behaviour of materials and to introduce the electrochemical methods for the experimental evaluation of their performance.

Part one: Metallic and organic coating for corrosion protection.
In this part the characteristics of metallic and organic coatings are illustrated. The student will be given the fundamental knowledge of the deposition methods, the characteristics of layers and the methodologies to highlight the properties and quality of these coatings.
The main topics are:

- Characteristics of metallic coatings;
- Galvanic process;
- Deposition of zinc, nickel and chromium coatings;
- Electroless deposition;
- Hot dip process;
- Methods for testing the quality of metallic coatings (microstructural analysis, corrosion behaviour, galvanic coupling);
- Organic coatings: characteristics, properties;
- Deposition process of organic coatings;
- Mechanism of corrosion protection of organic coatings.

Part two: electrochemical techniques for coatings characterisation.

- Fundamentals of the electrochemical degradation of metallic materials and physical measurable parameters.
- Overview of direct current electrochemical techniques (DC): polarisation curves.
- Examples of DC measurements: discussion of the mechanisms and the quantification of degradation.
- Overview of alternate current electrochemical techniques (AC): electrochemical impedance spectroscopy.
- Modelling metal degradation by EIS: equivalent electrical circuits.
- Examples of EIS measurements: discussion of the mechanisms and the quantification of degradation.
- Advanced electrochemical techniques: SVET, SRET Kelvin probe.

Exam: The final evaluation for 3 credits will consists in a multiple choice test. For the second part (+3 credits) the students will present a report describing laboratory experimental work using the techniques presented in the course.

Computational thermodynamics I

Teacher: Massimo Pellizzari
ECTS: 2
Content: The aim of the course is to introduce the basics of computational thermodynamics. The solution of different types of equilibrium calculations with the Thermo-Calc software will be addressed.

<u>Part 1: A short introduction to computational thermodynamics (4 hours)</u>

- The CALculation of PHAse Diagrams: the CALPHAD method.
- A definition for the thermodynamic equilibrium.
- Thermodynamic descriptions of the free energy G: available models.

The contributions to the free energy G of a binary phase:

Example 1: a binary stoichiometric phase.
Example 2: Binary solution phases, the *regular-solution* model.
Example 3: ordered binary solution phases, the *sublattice* model.

- Assessment (optimization) of a thermodynamic system.
- The extension of description of free energy for higher component (>2) phase.
- Definition of thermodynamic equilibrium in terms of chemical potential.
- Computer software tools and database.

<u>Part 2: The Thermo-Calc software package and databases (2 hours)</u>

- The general structure of the Thermo-Calc package.
- The modules of the Thermo-Calc software.
- The functionality of the Thermo-Calc software.
- Materials and industry-oriented applications of the Thermo-Calc software.
- Basic thermodynamic (state) variables and functions in Thermo-Calc.
- The Gibbs Phase Rule: monovariant and invariant equilibrium.
- Basic steps for equilibrium calculations using POLY3. Retrieving data from Database, Setting conditions, Calculating equilibria, Generating diagram properties, Plotting diagrams

<u>Part 3: examples of thermodynamic calculations (6 hours)</u>

- The calculation of the Fe-C phase diagram using the POLY-3 module of Thermo-Calc.
- Introduction to the in-line HELP of Thermo-Calc.
- Phase and property diagrams: use of the MAP and STEP command.
- The graphic post-processor: POST module.
- Calculation of the Fe-graphite (stable) and Fe-cementite (metastable) phase diagram.
- The calculation of an isopleth of the AISI M2 high speed steel. Kinetic limitations of the thermodynamic calculations.
- Thermodynamic modelling of solidification using the model of Scheil-Gulliver: simulation of microsegregation.

Exam: The students should prove their ability to solve a specific thermodynamic calculation proposed by the teacher using the Thermo-Calc software. A written report including graphical results must be provided.

Computational thermodynamics II

Teacher: Massimo Pellizzari
ECTS: 2
Content: Diffusional phase transformations are of great importance for processing control. In this course, the interplay of thermodynamics (analyzed during the first module *Computational Thermodynamics I*) and atomic mobility/diffusivity will be presented for multicomponent systems. DICTRA, a software package for simulation of DIffusion Controlled

TRAnsformations, will be used. This course shows how to combine thermodynamics and kinetics to simulate processes of practical importance such as homogenization, precipitation and dissolution.
Part 1: Introduction to diffusion-controlled transformations (6 hours)
- Diffusion in binary alloys
- Multicomponent diffusion
- Atomic mobility
- Diffusion in multicomponent systems
- Concentration dependent diffusion coefficients
- Diffusion database

Part 2: The DICTRA software
- Numerical procedure of DICTRA
- Atomistic treatment of diffusion
- The equations of diffusion
- Mobility and diffusivity
- The kinetic database
- Modelling steps
- Overview of mobility databases (MOB2)
- Concepts: cell, region, grid types, geometry

Part 2: Examples of calculations (6 hours)
- Carburizing of a Fe-C alloy
- Carbides dissolution
- Carbides coarsening
- Microsegregation during solidification
- Carbon diffusion between two steels

Exam: The students should prove their ability to solve a specific calculation proposed by the teacher using the Dictra software. A written report including graphical results must be provided.

Design and manufacturing of (nano)technologies for controlled release of biomacromolecules

Teacher: Annalisa Tirella
ECTS: 2
Content: The course aims at developing knowledge about: 1) technologies (nano and micro) as delivery vehicles, 2) use of microfluidic technologies for manufacturing of nano and micro particles, 3) role of the carrier materials for loading and release biomacromolecules.
The first part will cover fundamentals of materials science and engineering, biomaterials and biomedical technologies, and emerging technologies for the manufacturing of particles. With the acquired knowledge students will be able to formulate comprehensive answers to research questions arising the course content, by the end of the course, student will be able to design and manufacture technologies for controlled release.

ILOs:
Regular and active participation and independent research activities will enable students to:
1) Understand and explain the selection, the loading and the release mechanism of the 'carrier material-biomacromolecule' pair;
2) Evaluate and identify efficient mechanism to load biomacromolecules at the required dose, and identify critical quality attributes of particles;
3) Explain existing and emerging technologies used for the manufacturing of nano and micro particles;
4) Identify key features, design criteria and manufacturing parameters for the production of technologies used to control the release of macromolecules in known environments.

Teaching methods used and learning activities required of students
1) highly interactive lecture-style presentation during which students will be required to actively participate;
2) research themes given to small groups of students, who must discuss, analyze and present to the class the results achieved.The course will present, with a number of practical applications, the use of image analysis and electron diffraction phase identification and indexing programs applied to electron microscopy data to obtain quantitative microstructural data from images and crystallographic parameters from electron diffraction patterns.

Exam: 1) written exam with multiple choice question and open-ended questions to assess basic knowledge (contributing 50% of Final mark);
2) individual/group project (assigned topic) with design of a controlled release technology and oral presentation of the project (contributing 50% of Final mark, any additional points will come from evidence of critical thinking during the discussion of the project).

Electron microscopy techniques – Theory

Teacher: Stefano Gialanella
ECTS: 2
Content: Electron interaction with matter: secondary and backscattered electrons; x rays. SE and BSE detectors.
Principles of image formation. Magnification. A comparison among different scanning microscopes: CSEM, LVSEM e ESEM. Introduction to transmission electron microscopy. Chromatic and spherical aberrations; astigmatism. Electron diffraction methods: SAED, Kikuchi lines, CBED. Indexing of an electron diffraction pattern. Diffraction contrast: bright and dark field imaging. Mass thickness contrast; Phase contrast. Spectroscopy techniques in a TEM: and TEM. EDXS-and EELS. EDXS

qualitative and quantitative analysis. Sample preparation techniques for SEM and TEM.

Exam: Written exam: problems and exercises concerning different aspects and topics of the course.

Electron microscopy techniques - Practice

Teacher: Gloria Ischia
ECTS: 2
Content: The course will present, with a number of practical applications, the use of image analysis and electron diffraction phase identification and indexing programs applied to electron microscopy data to obtain quantitative microstructural data from images and crystallographic parameters from electron diffraction patterns.
Exam: Written exam.

Elemental analysis by X-ray spectroscopy – Theory

Teacher: Giancarlo Pepponi
ECTS: 2
Content: Primary interactions of X-Rays with matter:

- photoelectric absorption
- elastic scattering
- inelastic scattering (Compton)
- macroscopic attenuation

Reflection and Refraction of X-Rays:

- index of refraction
- Fresnel equations
- x-ray reflectivity (XRR)
- total reflection

Electrons interaction with matter:

- short overview
- Bremsstrahlung
- electron impact ionization

Secondary effects:

- X-Ray Emission/Fluorescence (XRF) vs. Auger electron emission

Intensity of emitted characteristic X-Rays:

- Sherman's equation

Instrumentation 1:

- sources: x-ray tubes, large facilities
- spectrometers: wavelength dispersive, energy dispersive (ED)
- ED detectors: response, efficiency, artifacts
- Optics: filters, monochromators, lenses, mirrors

Spectrum analysis

- qualitative analysis
- quantitative analysis
- software

(ED)XRF configurations and instruments:

- bulk analysis, large area
- micro-XRF, including the confocal set-up
- grazing incidence XRF (GIXRF) and total reflection XRF (TXRF)
- laboratory instruments and beamlines available at large facilities

Introduction to X-Ray Absorption Spectroscopy (XAS):

- principles: speciation, local structure
- experimental: transmission acquisition vs fluorescence acquisition
- mechanics of viscoelastic solids (w/ lab activities)

Exam: Written exam.

Elemental analysis by X-ray spectroscopy – Practice

Teachers: Mauro Bortolotti, Lorena Maines
ECTS: 2
Content: The course will illustrate, with a number of practical applications, X-ray spectroscopies using electrons and X-rays to induce secondary X-ray fluorescence for materials analyses. As concerns electron induced X-ray emission, the main instrumentation considered for the practical sessions are the energy dispersion X-ray spectrometers installed on electron microscopes. As concerns the X-ray induced fluorescence, XRF lab instruments adopting different detection configurations will be employed.
Examples of combined analyses, e.g., XRD-XRF, SAED-EDXS in TEM will be also presented.
Exam: Written exam.

Environmental sustainability of the materials

Teacher: Andrea Dorigato
ECTS: 2
Content: The course is focused on the environmental aspects associated to the use of the materials in the modern society: the eco-aspects of their production, their use, their disposal at end of life is analyzed. The way to assess the environmental impact associated to their use is also described.
Background concepts:

- Materials supply chain risk and critical materials.
- Energy, water and carbon footprint.
- Sustainable development: definition and assessment techniques.

End of first life options of materials:

- An overview of the end of life options of materials.
- Recycling: a key factor for resource efficiency, definition and terminology.

- Recycling of metals, paper, glass, cementitious binders and plastics.

Life Cycle Assessment (LCA):

- Definition.
- Description of the methodology and case studies with the aid of the software SimaPro.

Exam: Written exam.

Experimental mechanics of materials

Teachers: Alessandro Pegoretti, Vincenzo Maria Sglavo
ECTS: 3
Content: The aim of the course is to transfer competencies regarding mechanical behaviour of materials and basic experimental methodologies to analyse and measure fundamental mechanical properties. In particular, the following topics will be covered:

- evaluation strategies for measuring the mechanical properties of materials: tensile, compressive, flexural and torsion test.
- principles of fracture mechanics
- failure statistics
- indentation fracture and controlled cracks in brittle materials
- mechanics of viscoelastic solids

Exam: A written exam or a questionnaire.

Friction and Wear of Materials

Teacher: Giovanni Straffelini
ECTS: 3
Content: The aim of the course is to introduce students to the main topics of tribology, i.e., friction, wear and lubrication. Special emphasis is given to the behaviour of the different types of materials, and several engineering applications are presented and discussed.
The list of subtopics is:

- Contact mechanics;
- Friction and contributions to friction:
- Wear mechanisms;
- Surface engineering;
- Selected mechanical and manufacturing applications, where tribology plays a special role.

Specific numerical exercises and case studies will be also proposed to improve the capability of using the tribological concepts.
Exam: The final evaluation consists of an oral examination.

Materials science and technology

Teacher: Luca Fambri
ECTS: 3
Content: This course provides the base principles in materials science and technology to those students of the Doctoral School who intend to follow a curriculum based on these subjects, not having a suitable cultural background from previous studies. The course will consider the main classes of materials, as concerns their properties, their dependence on microstructure and phase transformations. The detailed program will be established on the basis of the actual composition and specific interests of the attending group.
Exam: Written exam containing problems and exercises concerning different aspects and topics of the course.

Optical properties of nanomaterials

Teacher: Alberto Quaranta
ECTS: 2
Content: The aim of the course is to develop skills in the use of optical techniques for the characterization of materials and nanomaterials.
The main topics treated during the lectures will be.

- Light propagation in matter.
- Optical parameters of materials.
- Instrumentation and analysis techniques.
- Thin film optical characterization.
- Light scattering on nanomaterials.
- Luminescence spectroscopy of materials and nanomaterials.
- Applications of nanomaterials as related to their optical properties.

Exam: The final examination will consist of a short seminar on the applications of optical analysis techniques on a topic related to the student's research interests or on an argument treated during the course.

Point defect chemistry, diffusion, and charge transport in ceramics

Teacher: Mattia Biesuz
ECTS: 2
Content: Point defect chemistry is crucial for understanding, rationalizing, and designing materials' properties.
Moreover, it controls diffusional processes which impact phase transitions kinetics, sintering, diffusional creep, solid-state reactions…
In this course, the main concepts related to the point defect equilibria in ceramics are introduced and correlated with charge and mass transport in ceramics.
The main content will be:

- Introduction to point defects in ceramics (Schottky, Frenkel, Ant-Frenkel…) and their reactions according to the Kröger–Vink notation
- Approaches for measuring the point defect concertation
- Extrinsic vs. intrinsic point defects

- Point defect concentration dependency on dopants, temperature, and atmosphere (Brouwer diagrams)
- Defects association and space charges
- Ambipolar diffusion in ionic crystals
- Ionic/electronic conductivity dependency on point and interface chemistry
- Approaches for measuring ionic/electronic conductivity aim of the course is to develop skills in the use of optical techniques for the characterization of materials and nanomaterials.

Exam: Oral exam.

Qualification SEM and TEM

Teachers: Gloria Ischia (SEM-TEM), Lorena Maines (SEM-TEM), Antonella Motta (FESEM)
ECTS: 2 (each Qualification)
Content: Students who are interested to get the *qualification* for a direct use of the EM equipment, can take this exam after early stage training (12h), to be completed up to 40 h to be fully entitled to an autonomous access and direct usage of SEM and /or TEM. A practical exam at the end of the course is required.

Scanning probe microscopy – Theory and Practice

Teacher: Devid Maniglio
ECTS: 2
Content: Physics and working principle of scanning probe microscopy, nano- and micro-displacement sensors and actuators
Actuator working principle: piezoelectricity, displacement control. Atomic Force Microscopy (measurement principle, measurement modes: contact, noncontact, F(z), probes and samples surfaces: materials and preparation, data acquisition and analysis). Scanning Tunnelling Microscope (measuring principles, measurement modes: constant current, constant distance, spectroscopy). Special SPM techniques MFM, CFM, molecular recognition force microscopy (MRFM), dip-pen lithography, force lithography, Molecular recognition.
Exam: Written exam.

Synchrotron-based techniques for characterization of materials

Teacher: Barbara Rossi
ECTS: 2
Content: There are many advantages in the use of synchrotron radiation (SR) compared to conventional "laboratory" source for the characterization of materials. First of all, the high brightness, wavelength controlled and tunable emission of SR allows to tune in a very efficient way cross sections and atomic edges of the systems under investigation. The SR emission is a coherent and multiply polarized radiation that can be used for probing dichroic effects and bonding orientation. Finally, there are a great variety of SR-based spectroscopies that provide elemental, chemical and magnetic information and a large variety of imaging contrasts based on photon absorption, scattering or spectroscopic feature. The purpose of this course is to giving an overview of the SR-based techniques useful for the characterization of materials, providing to the students the fundamental knowledge needed for successfully applying for obtaining beamtime at SR facilities.
The following topics will be presented and discussed:

- SR production and operation of SR sources;
- SR-based spectroscopic techniques: Infrared Absorption and UV Resonance Raman scattering;
- Examples of experiments for characterization of materials (disordered systems, materials of interest for cultural heritage, biological systems);
- Writing a successfully proposal for obtaining beamtime at SR facilities

Exam: Written final exam.

Thermal analysis

Teachers: Luca Fambri, Massimo Pellizzari
ECTS: 2 + 2(lab.)
Content: Part 1 (2 credits)
Module 1: applications of thermal analysis to materials characterization (Fambri L., 6 hours):

- Materials characterization by Differential Scanning Calorimetry (DSC).
- Materials characterization by Thermogravimetric Analysis (TGA).
- Materials characterization by Dynamic Mechanical Thermal Analysis (DMTA).

Module 2: • The study of phase transformations using thermal analysis (Pellizzari M., 6 hours):

- Study of phase transformations by Differential Scanning Calorimetry, Differential Thermal Analysis and dilatometry.
- The use of isothermal and non isothermal techniques to evaluate the kinetics of phase transformation.
- Evaluation of thermal stability of materials.

Exam: For each module the student must pass a final written test. The final mark will be determined as an average and worth 2 credits. For the additional (+2) lab. credits, the student will be asked to agree with one of the teachers an individual laboratory activity, possibly related to her/his PhD research program.

X-ray diffraction: theory and applications to materials science and engineering

Teacher: Luca Lutterotti, Mauro Bortolotti
ECTS: 2 + 2(lab.)
Content: The student after the course should be able to perform correctly a diffraction experiment for the kind of material he is aiming at determine the structural and microstructural features and analyse the data using the more appropriate methodology.

Part 1, theory and methodologies:

- General principles of crystallography and diffraction.
- Search-match techniques.
- Indexing and ab initio structure solution.
- The Rietveld method and structural refinements.
- Microstructural analysis: crystallite sizes, microstrains, texture, residual stresses.
- Special techniques: coupling with fluorescence analysis, thin films, amorphous, layered and disordered materials.

Part 2, laboratory practice (samples provided by the instructor or by the students may be used):

- General principles and use of a diffractometer; X-ray safety regulations and precautions.
- Sample preparation, choice of the correct measurement parameters and measurement.
- Analysis of the data, assessment of the results.

Exam: The student will analyse some data provided by the examiner choosing the correct methodology and software from the ones indicated in class. In alternative, the student may choose also other methodologies/software provided the final results are corrects.

Mechatronics and Mechanical Systems

Design of transducers based on smart materials and structures for robotics and energy harvesting

Teacher: Marco Fontana
ECTS: 2
Contents: The course provides a broad overview on mechanical transducers based on multifunctional materials and structures, with a specific focus on recent developments in these fields. Two classes of transducers, that are particularly promising for their energy/power densities and efficiency are mainly considered which are based on: (1) dielectric elastomers and (2) coiled/twisted polymeric fibers/lines. Basic models that are able to describe the mechanical response of these materials/structures are illustrated. Additionally, principles for the design and control of actuators, energy converters and sensors that make use of these materials and systems are shown through different case studies.
Exam: Oral exam.

Introduction to systems biology

Teachers: Giulia Giordano
ECTS: 3
Content: The complexity of systems in the life sciences increasingly requires an interdisciplinary investigation, relying on the joint efforts of biologists, chemists, physicians as well as mathematicians, physicists, computer scientists and engineers. A quantitative and model-based study of biological systems is facilitated by the progress of omic- technologies (genomics, proteomics), which makes huge amounts of data available. In this context, systems biology has emerged as a strong network of disciplines concerned with the integrated and holistic study of the interactions between the components of biological systems, and of how these interactions give rise to the overall function and behaviour: systems biology aims at understanding the design principles of life with system-theoretic tools and techniques.

The course discusses:

- An overview of systems biology and quantitative approaches to the life sciences
- Basic network motifs in biology and examples of biomolecular systems: dynamic models of core processes
- Analysis of dynamic behaviours
- Fundamental properties: robustness and structural properties; modularity; optimality.

The course topics are based on recent papers in the scientific literature, as well as on the books:

- Uri Alon, An Introduction to Systems Biology: Design Principles of Biological Circuits, Second Edition, Chapman & Hall/CRC Computational Biology Series, 2020
- Domitilla Del Vecchio and Richard M. Murray, Biomolecular Feedback Systems, Princeton University Press, 2014.

Exam: Individual project and oral presentation on a topic of choice.

Mathematical epidemiology - modelling, parametrization and applications

Teacher: Daniele Proverbio and Giulia Giordano
ECTS: 3
Content: The course covers the sections on "Mathematical Epidemiology" from the book "Mathematical Modeling for Epidemiology and Ecology" by Glenn Ledder, complemented with a rapid introduction on Agent-Based Modelling and an overview of recent research directions.
Prerequisites: the course assumes preliminary knowledge of mathematical modelling, probability, continuous dynamical systems and coding.
Preliminaries: the concept of mathematical modelling, modelling selection (Chi squared and Akaike information criterion) and its practical value; algebraic vs ABM models (overview); introduction to parameters and bifurcations. Example: continuous SIR vs ABM.
Body of the course:

1. Types of bifurcations and relationships with parameter properties.
2. Mechanistic epidemiological models: Vaccination models and derivation; Holling model for vaccination with finite resources; The SEIR model and its extensions: compartment models, assumptions, qualitative behaviour of the base model and of noteworthy extensions (saddle-node in vaccination models, period-doubling with seasonal forcing, chaos due to behavioural feedback); Introduction to two-disease models. Examples of coding: SEIR and SEIR + seasonal forcing.
3. COVID-19 case study: SEAIHRD, analysis from the book; Existence of other models and formulations: SIDHARTE; SPQEIR (extended to hospitalisation); Age structure.
4. Best fitting: MCMC, dual annealing, state-of-the-art methods.
5. Back to nonlinear stability: Graphical methods and linearization. Jacobian analysis; the Routh-Hurwitz Conditions. Phase plane analysis, nullclines and slow-fast dynamics. Nullcline analysis of SEIS models.

Selected examples are proposed at each step of the course.
Exam: Project.

Mechanical vibrations in spacecraft design

Teacher: Daniele Bortoluzzi
ECTS: 2
Content: The course collects typical topics of mechanical vibrations which are used in the design of spacecraft structures and are usually addressed in different references. Placing spacecraft or satellites into an orbit constitutes a severe test for the launch vehicle – payload system since propulsion, aerodynamics, acoustic and shock loads interact with their overall dynamic characteristics and introduce mechanical vibrations which can affect their functionality or even integrity. The design of spacecraft, payloads and their interfaces must take into account their structural response under the action of forces of different nature. The topics addressed in the course are the following:
Linear dynamic systems. Modal analysis. Modal effective mass. Response Analysis. Transient response Analysis. Shock-response spectrum. Random vibration of Linear Dynamic Systems.
Exam: Discussion of an individual project preferably in the frame of the PhD research.

Modeling with Partial Differential Equations

Teachers: Giacomo Moretti
ECTS: 3
Content: The course aims to teach students to translate their physical understanding of a continuum system into a set of partial differential equations (PDE), and tackle their solution via analytical and numerical tools. The first part of the course will present the students with a gallery of examples of relevant problems/examples pertaining to different physical domains (mechanical, electrical, thermal, fluidics). The focus will be then set on analytical methods (separation of variable) and numerical tools (finite elements) for the solution of PDEs.
The following outline will be followed:

- Introduction on PDEs, classification
- Modelling: gallery of physics problems leading to PDEs
- Analytical solution methods: separation of variables (foundations base cases, Green functions and advanced approaches)
- Numerical laboratory: solution of PDEs with Comsol Multiphysics' PDE solver.

Exam: Solution of a Homework/project work + oral presentation/discussion. Homeworks might be based on relevant problems proposed by the students, or suggestions/papers assigned by the teacher.

Network dynamics

Teacher: Giulia Giordano
ECTS: 3
Content: Networked dynamical systems, composed of several dynamical subsystems that are interconnected according to a network topology, are ubiquitous in our daily life: transportation networks, data communication and telecommunication networks, power networks, sensor networks, production and distribution networks, social networks, biological networks are all endowed both with a dynamic behaviour and with an inherent network topology. The course introduces mathematical notions, at the edge between graph theory, dynamical systems and optimisation, that help model, analyse and control dynamical networks, focusing on the common principles of connectivity and resilience, centrality and influence, which arise in several different domains.
The course discusses:

- graph and network theory: graph properties (un/directed, weighted, balanced, regular, simple graphs) and definitions (concepts of walk, path, cycle, distance, diameter);
- algebraic graph theory: matrices associated with graphs (adjacency/weight matrix, degree matrix, Laplacian matrix, normalised adjacency/weight matrix) and their spectral properties based on Gershgorin's circle theorem and on Perron-Frobenius theory for nonnegative matrices; node-link, path-link, path-node incidence matrices;
- network connectivity, connected components and size of the associated eigenspaces; Menger's theorem;
- network flows, capacity, cuts, max-flow min-cut theorem, resilience of transportation networks to capacity losses;
- network centrality measures: degree, eigenvector, Bonacich, Katz, PageRank, betweenness and closeness centrality;
- linear dynamics defined over networks, both in discrete time and in continuous time: distributed averaging systems, opinion dynamics and consensus, also with stubborn agents; linear flow dynamics, open and closed compartmental systems;
- optimisation of network flows: social optimum and user optimum flows, Wardrop equilibrium, Braess paradox, price of anarchy, tolls;
- network epidemics and contagion: interactions between susceptible, infectious and recovered individuals; SI, SIR, SIS models.

Applications will include dynamics and control of transportation and power networks; sensor networks; opinion dynamics in social networks; pharmacodynamics and chemical reaction networks; spreading of diseases and cascading failures.
Exam: The final evaluation will be based on the solution of a written assignment and the preparation of an individual project.

Neural Networks for Mechanics

Teacher: Gastone Pietro Rosati Papini
ECTS: 3
Content: The purpose of the course is to present students how to use neural networks in the mechanical domain for the purpose of modelling or controlling mechanical devices. The classic deep learning needs a multitude of data to work properly, as the number of parameters used is very high, in this course will show the synthesis of neural networks of small size that lay their foundation on the physical laws of the model analysed, thus reducing the data needed for training and the ability of the network to generalize correctly.
The course will address in order:

1. introduction to neural network theory: basic elements and back-propagation.
2. examples of structured networks for modelling and vehicle control
3. a project will be proposed to deepen these topics.

Exam: The final evaluation consists in a project on the proposed topic.

Non-linear hybrid dynamical systems

Teacher: Luca Zaccarian
ECTS: 3
Content: This course will provide the student with the fundamental tools behind the recent framework developed by Goebel, Teel and Sanfelice for the description of hybrid dynamical systems. The course will begin with a brief overview of the essential results behind Lyapunov-based nonlinear continuous-time dynamical systems analysis (a good reference for this may be Hassan Khalil's "Nonlinear Systems" book by Prentice Hall). The continuous-time results will be used as a track to follow when introducing the corresponding generalized notions for hybrid dynamical systems: solution concepts, asymptotic stability, Lyapunov functions and invariance principles. Several examples will be given during the course to motivate the mathematical tools that will be progressively introduced. The majority of the course will be based on the recently published book: "Hybrid Dynamical Systems: Modeling, Stability, and Robustness, Princeton University Press", which will also serve as a reference for the course material.
During the course we will also illustrate how the simulation of hybrid systems can be performed in a Matlab environment with suitable tools. The last lectures will address some recent research activity on two control-related topics where the hybrid tools introduced in the course will be useful. A detailed schedule follows:

- Introduction and examples (chapter 1 from the hybrid book).
- Solution concept + Uniform Global preAsymptotic Stability without Lyapunov (chapter 2 and part of chapter 3).

- Lyapunov functions, generalized solutions and results from set-valued analysis (rest of chapter 3, selected topics from chapters 4 and 5).
- Robust and non-robust local asymptotic stability, regions of attractions and Lyapunov functions (selected topics from chapter 6, most of chapter 7).
- Matlab session: I will illustrate the use of Ricardo Sanfelice's simulator and of a simpler simulator developed for dwell-time systems (things become a lot easier in this last case). We will use standard examples: bouncing ball, reset control systems, sampled data systems.
- Reset control systems: an interesting story starting in the 1950's from Clegg integrators and First Order Reset Elements, and revisited recently with analytic and numerical Lyapunov functions, necessary and sufficient conditions for stability, extensions to more complicated Lyapunov-based resets and application to Diesel engine EGR valve control.
- Mirroring and billiards: this topic will allow us to introduce exponential stability, invariance principles and a number of related results while in parallel focusing on an interesting application arising in control of mechanical systems with impacts.

While the initial idea is to cover the above mentioned topics, based on the needs of the student group, changes may be made to the topics covered and the schedule. Most of the lectures will be taught on the blackboard.

Exam: The final evaluation will be carried out based on an oral exam, and possibly also a written exercise.

Numerical optimal control: basic theory and applications

Teacher: Francesco Biral
ECTS: 3 + 1 (lab.)
Content: This course will provide the student with the fundamental concepts of optimal control and the knowledge to solve engineering application using both Direct and Indirect Method with extensive tutorials and use of state of art tools. The course focuses more on the Indirect Method and the use of PINS software developed by E. Bertolazzi, F. Biral, and P. Bosetti. The course is based on four parts.

- Introduction to Optimal Control: optimal control formulations, solution methods for optimal control.
- Direct method: theoretical basis, solution approaches and examples.
- Indirect method: Calculus of Variation and Pontryagin's Minimum Principle, Calculus of variations, Necessary Optimality Conditions, Sufficient Conditions of Optimality, Singular Arcs, explicit expression for controls, analytical solutions. Indirect Method Pro & Cons.
- Finite horizon and infinite Horizon problems.
- Numerical solution of Indirect Methods using PINS library: overview, tutorials and application examples.

Based on the needs of the audience, changes in the presented arguments and schedule can be performed.

Exam: The final evaluation will be carried out based on an oral exam possibly comprising an individual course term project.

Numerical optimization. Algorithms and practical implementation

Teacher: Enrico Bertolazzi
ECTS: 3 + 2 (lab.)
Content: The course provides an introduction to state-of-the-art numerical algorithms for the minimization of multivariate functions.
These algorithms are categorized into four groups:

- Derivative free algorithms
- Algorithms based on gradients only
- Algorithms that use gradients and hessians
- Evolutionary algorithms

The most important taught algorithms are:

- Gradient methods and Zoutendijk condition
- Conjugate Gradient-based methods (Fletcher and Reeves, Polack and Ribiere, …)
- Quasi-Newton Methods (Broyden, DFP, BFGS, …)
- Trust Region (DogLeg)
- Particle Swarm and differential evolution.

Constrained and unconstrained minimization are taken into consideration. Due to the large number of treated topics and proposed algorithms, only selected ones are studied based on the interest of attending students.
For the considered algorithms an implementation using MATLAB, Julia or C++ is provided and students are forced to develop their own version.

Exam: The final assessment wiil be conducted through individual projects related to the topics covered in the course.

Object Detection for Automotive Applications and Space Exploration: reliability opportunities and challenges

Teacher: Paolo Rech
ECTS: 2
Content: The main goal of this course is to provide students with an overview of the challenges associated with the hardware and software necessary for an application, such as object detection, that represents one of the major advances in the technology for computing devices. All the major cars builder and chip designers are targeting self-driven vehicles. Moreover, autonomous vehicles are extremely useful for space exploration. The NASA's JPL Perseverance mission lunched at the end of July 2020, for

instance, includes the first autonomous vehicle used for space exploration. The next ESA/NASA Mars samples return mission will be composed of fully autonomous rovers and drones. The course proposes a revision of basic concepts of real-time systems, parallel or programmable architectures, safety-critical systems, and approximate computing. These concepts are used and applied to deeply understand the object detection frameworks based on neural networks and their application in automotive and aerospace markets. A study of the limitations in terms of reliability and of the problems that can affect the correct execution of software and hardware will be presented. The focus will be on the study of both the hardware and the software necessary to detect object in a scene in real time. The problems and the constraints related to the security and reliability that can influence a safety-critical system will be considered.

The main topics covered during the course are:

- Introduction. Safety-critical applications concepts
- Automotive and aerospace applications
- Parallel and Programmable processors
- Approximate computing and energy consumption
- Object detection: state of the art
- Convolution and Activation function
- Neural networks based object detection
- CNNs in GPUs and FPGAs
- GPUs, FPGAs, what else? Automotive vs Aerospace
- Standard ISO 26262.
- Faults in hardware, errors in software.
- Hardening techniques for object detection.
- Energy consumption, execution time, precision, fault tolerance: can we have it all?

Exam: Discussion over a project to be developed during the course.

Object oriented modeling and simulation of multi-physics dynamical systems

Teacher: Francesco Biral
ECTS: 3 + 1 (lab.)
Content: This course will provide the student with the fundamental concepts of the modern object oriented simulation approach for multi-physics dynamical systems. The approach is based on network of individual equation-based sub-models supported by the open language Modelica ©. This allows for systems which consist of many components from different domains (e.g. mechanics, control engineering, fluid power, thermal etc.) to be modeled in a very efficient way. Developed models are a-causal (i.e. elements are linked through physical connections with no need to take the operating direction into account).

- Introduction and dynamical system modelling approaches
- Overview of Modelica language and Modelica based simulation softwares
- Theoretical basis of object-oriented, a-causal modelling, physical based modelling: reusability, and hierarchical structure and evolution of large and complex models,
- Equation generation, manipulation, simplification and solution methods
- Generation of model for real time solution
- Modelling and Simulation of Multidomain systems (examples)

Based on the needs of the audience, changes in the presented arguments and schedule can be performed.

Exam: The final evaluation will be carried out based on an oral exam possibly comprising an individual course term project.

Optimization-Based robot control

Teacher: Andrea Del Prete
ECTS: 2
Content: The course provides an overview of state-of-the-art techniques for the dynamic control of robotic systems, with a specific focus on legged robots (bipeds and quadrupeds) and robot manipulators. The course covers both theory and implementation, relying on the Python language and some existing libraries for robot visualization, multi-body dynamic computation, and trajectory optimization.

The course is split in two parts, covering the following topics:

*** PART 1

- Modeling of multi-body systems (recap)
- Modeling of legged robots
- Inverse-Dynamics Control (aka Computed Torque, or Feedback Linearization)
- Task-Space Inverse Dynamics (TSID), aka Operational-Space Control, Stack of Tasks
- QP-based TSID (with inequality constraints)
- Implementation exploiting an existing C++ library with Python bindings

*** PART 2

- Linear Inverted Pendulum Model (LIPM)
- Center of Mass Trajectory Generation with LIPM
- Foot-step Planning
- Implementation in Python (exploiting existing library)
- Connecting Part 2 with Part 1 to get a legged robot walking in simulation

Exam: The final exam consists of answering a few open questions by writing short Python scripts.

Robot learning from demonstration

Teacher: Matteo Saveriano
ECTS: 2
Content: The course provides an overview of state-of-the-art approaches for robot learning from human demonstration. The course will focus on approaches that allow the robot to learn stable (in the sense of Lyapunov) discrete (point-to-point) and periodic (limit cycle) trajectories evolving in the Euclidean space. We then move to more complex space structures and introduce the concept of Riemannian manifold with a special focus on orientation and symmetric and positive definite matrices that are of interest in robotics. The presented mathematical tools will be then used to perform learning of motion patterns evolving on Riemannian manifolds. The course covers both theory and implementation of presented algorithms relying on existing, open-source implementations.
The course is split in two parts, covering the following topics:
*** PART 1
- Introduction to dynamical systems and Lyapunov stability theory.
- Introduction to density estimation with Gaussian mixture models.
- Learning stable, time-dependent dynamical systems (Discrete Dynamic Movement Primitives).
- Learning stable limit cycles with Periodic Dynamic Movement Primitives.
- Learning stable, autonomous dynamical systems (Stable estimator of dynamical systems, postlearning stabilization, learning via diffeomorphisms)

*** PART 2
- Introduction to differential geometry and Riemannian manifolds (Unit quaternion and symmetric and positive definite matrices)
- Discrete and periodic Geometry-aware Dynamic Movement Primitives.
- Learning stable, autonomous dynamical systems on manifolds.

Exam: The final evaluation will be carried out based on the preparation of an individual project.

Saturated control systems

Teacher: Luca Zaccarian
ECTS: 3
Content: The magnitude of the signal that an actuator can deliver is usually limited by physical or safety constraints. This limitation can be easily identified in most common devices used in the process industry, such as proportional valves, heating actuators, power amplifiers, and electromechanical actuators. Common examples of such limits are the deflection limits in aircraft actuators, the voltage limits in electrical actuators and the limits on flow volume or rate in hydraulic actuators. While such limits obviously restrict the achievable performance, if these limits are not treated carefully and if the relevant controllers do not account for them appropriately, peculiar and pernicious behaviors may be observed (aircraft crashes, Chernobyl nuclear power station meltdown).
This course addresses stability analysis and stabilization of linear systems subject to control saturation. We will discuss a first approach consists in designing a (possibly nonlinear) controller directly accounting for the saturation constraints. Then we will present the so called anti-windup approach, where an anti-windup augmentation is inserted on an existing control system which "winds up" (performs undesirably) due to actuator saturation. The anti-windup feature is then to preserve the predesigned controller before saturation is activated and to recover stability for larger saturated responses. Anti-windup solutions differ in architecture and performance achievements. We will discuss several architectures suited for different saturation problems. Simulations and a few applications will be used to illustrate the presented techniques.
Exam: The final evaluation will be carried out based on the preparation of an individual project.

Scientific computing

Teacher: Enrico Bertolazzi
ECTS: 3 + 3 (lab.)
Content: This course will familiarize students with the efficient implementation of selected numerical analysis algorithms.
As an example of possible arguments:
- Sort and searching
- Matrix factorization
- Adaptive quadrature
- Runge Kutta and other methods for ODE.

All the examples are created using C++11 with the EIGEN3 library. An introduction to Object-Oriented programming is integrated into the course. Modifications to the topics covered and schedule can be made to accomodate the audience's requirements.
Exam: The final evaluation will be carried out based on individual project on arguments proposed in the course.

Simulating autonomous car dynamics with IPG CarMaker

Teacher: Antonello Cherubini
ECTS: 3
Content: All self-driving vehicles need a special piece of software that allows them to bring passengers to their destination. This software is called 'agent'. It takes into account conventional vehicle dynamics together with high-level decision making strategies. Using a professional-grade simulation environment like CarMaker is key to managing the complexity of

autonomous agents and ensuring that the software meets the desired specs and safety criteria.
In this course, PhD students will have the unique opportunity to learn how to use CarMaker, combining theoretical foundations and hands-on experience. The classes will start from basic vehicle modeling and will go all the way up to scripting multiple simulations with custom 3D interfaces.

Max number of participants: 4

Exam: Oral presentation on a topic of choice.

Vision-Language-Action Models for Robotics and Autonomous Vehicles

Teacher: Alice Plebe e Mauro Da Lio
ECTS: 2
Content: This course is designed to introduce PhD students to a groundbreaking perspective gaining traction in the fields of robotics and autonomous vehicles: the Vision-Language-Action Models (VLAM). They center around the utilization of Neural Language Models (NLM), a revolutionary development in artificial intelligence over the past five years. These NLMs, driven by the transformative neural architecture called the Transformer, initially dominated natural language processing. However, their success led to expansion into diverse domains, including image processing, and more recently, autonomous driving. Leveraging NLMs, especially their attention mechanism, bridges the gap between autonomous systems and human-like common sense understanding. This paradigm shift also extends into the realm of robotics, with the emergence of Robotics Transformers that blend control systems and NLMs to enhance interaction with the environment.
The main topics covered during the course are:

- introduction - key challenges for robotics and autonomous vehicles;
- common sense reasoning in robotics and autonomous driving;
- overview of the Transformer;
- embedding and tokenization;
- the attention mechanism and its components;
- direct implementation of simple NLM
- methods for video tokenization;
- methods for control signals tokenization;
- examples of NLM-based systems in robotics;
- examples of NLM usage in autonomous vehicles.

Exam: Oral discussion, or development of a simple project agreed with the teacher.

Wave approaches to vibration control

Teacher: Emiliano Rustighi
ECTS: 3
Content: Mechanical vibrations affect in a positive or negative way the efficiency, the strength and the ergonomic of many engineered structures. Vibration is caused by dynamic loads arising during operation, e.g. in all transportation vehicles, motors/generators and buildings. It is also an invaluable diagnostic tool for monitoring the long-term health of structures. This module aims to provide an in-depth physical understanding of and an ability to implement the wave approach for modelling vibration. The course concerns the physics and modelling of wave propagation in structures and solids. The theories and formulations covered by the course are applicable within structural and mechanical engineering. Firstly, an introduction is given to the basic properties of body waves in an elastic continuum. The formulation of theories for wave propagation in one-dimensional structures, including bars and beams is considered. The concepts of dissipation, dispersion, reflection and transmission in one-dimensional waveguided will be discussed. Wave propagation in plates and in shell (pipe) is also presented. Experimental techniques are covered and some recent practical applications will be given.
Syllabus:

1. Introduction to wave interpretation and dispersion curves
2. Elastic wave motion in strings, rods and beams
3. Waves in rods and beams – energy flow and damping
4. Waves in beams – forcing, reflection and transmission
5. Waves in plates
6. Vibration control
7. Experimental techniques (measurements of the dispersion curves and realization of anechoic ends)
8. Practical applications (Mapping the underworld, leak detection, anechoic end, ice removal)

Required background: The participant must have a solid background in continuum mechanics and partial differential equations. Experience with numerical methods and programming is strongly recommended. The participants are expected to read the texts in the literature list before the course. The literature will be available upon registration.
Exam: The final evaluation consists in the completion of a project assignment.

Electronic Systems and Integrated Microelectronic Systems

Designing and programming the Internet of Things (IoT).

Teacher: Davide Brunelli
ECTS: 3
Content: The course provides an overview of the main platforms and technologies for the development of Internet of Things (IoT) products and services—including devices for sensing, actuation, processing, and communication. The course will improve the design skills and experiences to employ in developing novel systems. The course has theory and lab sections and the lab sections consist of hands-on and practical IoT exercises of fast prototyping sensing, actuation and communication for IoT devices with WiFi-microcontrollers and multi-core programmable platforms (e.g. the Raspberry Pi Platform).
The course covers the following topics:
- Definition of IoT, architectures and challenges.
- Programmable platforms for IoT fast prototyping (microprocessors and microcontrollers).
- Design flow and development tool-chains.
- Fundamentals of Real-time Internet of Things.
- Exploiting existing Cloud services for IoT backend.

Exam: The final exam consists of a multiple-choice test or a project for interested students.

Fundamentals of statistical estimation theory

Teacher: Daniele Fontanelli
ECTS: 3
Content: The course provides an overview of estimation algorithms that are most commonly applied in engineering problems. The course will improve the background knowledge to model, analyse and solve estimation problems. The course has theory and practical sections, mainly simulative. Depending on the availability of actual components, practical examples on actual software/hardware solutions are foreseen.
The course covers the following topics:
- Background on stochastic processes and random variables
- Minimum Variance Unbiased Estimators
- Cramer-Rao lower bound
- Best linear unbiased estimator
- Maximum Likelihood estimation
- Weighted least squares solutions
- Bayesian estimators

All the treated topics will be given with examples and hands-on problems.
Exam: The final exam consists of a multiple-choice test or a project for interested students.

Image sensors

Teacher: Lucio Pancheri
ECTS: 3
Content: This course offers an introduction to the fundamentals of image sensing, from the basic principles of light detection in semiconductors to the most up-to-date imaging technologies. Although the lectures are mainly focused on image sensor IC operation and characteristics, the course is also intended to convey a general view of related system and application issues. The following topics are covered:
- Fundamentals of radiation detection.
- Image sensors characteristics and measurement.
- CCD image sensors.
- CMOS image sensors.
- Color detection and color imaging.
- X-ray image sensors.
- Thermal and THz imaging.
- Range image sensors.
- Silicon image sensors for special applications: low-light level imaging, high dynamic range, time-resolved imaging.

Required background: basic analog and digital electronics.
Exam: Oral presentation on a topic of choice and discussion.

Measurement methodology and electronic instrumentation

Teacher: Dario Petri
ECTS: 3
Content: The aim of the course is to provide students with basic knowledge regarding measurement and the necessary knowledge for a rational use of electronic instrumentation.
Definition of measurement. Types of measurement scales.
Methodology of measurement: different activities required by a correct measurement process.
Basic block diagram of digital multimeters and measurement of waveform parameters.
Basic block diagram of digital oscilloscopes and measurement of waveform behaviours.
Input circuits of electronic instrumentation: normal mode rejection ratio; common mode rejection ratio; loading effects.
Uncertainty model of electronic instrumentation: sources of static and uncertainty; calibration diagram; sources of dynamic uncertainty.
The concept of quality. Definition of quality. Quality management methodologies.
Exam: The final evaluation will consist in a multiple-choice test.

Laboratory of Electronic Instrumentation

Teacher: David Macii
ECTS: 3
Content: This course relies on the module "Measurement methodology and electronic instrumentation" and it will be focused on some hands-on lab experiences and practical issues related to the use of basic measurement instruments such as digital multimeters, function generators, digital storage oscilloscope and spectrum analyzers. Particular attention will be devoted to the evaluation of measurement uncertainty. The topics of the course are listed below:

- Basic metrological definitions according to the International Vocabular of Metrology.
- Evaluation of measurement uncertainty based on the" Guide to the expression of uncertainty in measurement" - theory and examples
- Use of power supplies, waveform generators and digital multimeters in AC and DC mode: issues, tips and pitfalls
- Use of the Digital Storage Oscilloscope: probes, trigger conditions, metrological performances and examples of applications
- The spectrum analyzer: principle of operation and practical examples

Exam: The exam will consist of a report in which Students are required to summarize the results of the lab experiments performed during the course.

Silicon radiation detectors

Teacher: Gian-Franco Dalla Betta
ECTS: 3
Content: Silicon radiation detectors are widely employed in several fields of fundamental and applied research, as well as for medical imaging and industrial diagnostics. The aim of this course is to provide students with basic knowledge about silicon radiation detectors, related fabrication technologies and application fields.
The following topics are covered:

- Introduction. Application fields.
- Interaction between radiation and silicon.
- Operation principle of silicon detectors, Signal formation, Ramo's theorem.
- Signal processing: spectroscopic chain, noise considerations.
- Figures of merit: responsivity, quantum efficiency, detection efficiency, response speed, spatial resolution, energy resolution, radiation hardness.
- Categories and variants of silicon sensors: Photodetectors: photoresistors, photodiodes, phototransistors, colour sensors. Detectors for spectroscopy: PIN diodes, drift detectors. Position sensitive detectors: strip detectors, pixel detectors.
- Fabrication technologies: general aspects. Detailed description of 2 case studies.
- Simulation and design methodologies for silicon detectors
- Radiation damage: Bulk and surface radiation damage in silicon detectors. Radiation hardening by design and technological solutions.
- Detectors with three-dimensional electrodes (3D detectors). Operation principle, simulations, technology, selected results, radiation hardness. Active edge detectors. Applications other than high energy physics: neutron detection, FELs, dosimetry.
- Avalanche based detectors: impact ionization effects, different detector types (APD, LGAD, SPAD).
- The Silicon PhotoMultiplier (SiPM).
- Monolithic Active Pixel Sensors: The CMOS MAPS approach: general features, pros and cons, examples of implementations. Monolithic integration of transistors and detectors on high resistivity silicon: pioneering works, the DEPFET, other relevant results.

Required background: Basic knowledge of semiconductor device physics and electronics.
Exam: Oral presentation on a topic of choice and discussion.

The electrification behind the green revolution

Teacher: Elisabetta Tedeschi
ECTS: 3
Content: The aim of the course is to provide the students with an introduction to the technologies and trends that are enabling the transition towards a more sustainable society. It will be illustrated how renewable and distributed energy resources, coupled to the increasing electrification of industrial processes and mobility, can reduce the global energy needs and especially the consumption of traditional fossil fuels.
The lectures will cover:

- The electrification process and its motivations. Basics of the enabling technologies underpinning it, such as power electronics and electric drives.
- An overview of the main renewable energy generation technologies (wind, solar, emerging energy sources…), their evolution over time and their current challenges and trends.
- The progressive change in the traditional power system through converters' integration, and the spread of new and more efficient energy paradigms (e.g., microgrids/smart grids) to enable the full exploitation of distributed energy resources.
- Analysis of more sustainable energy consumption patterns: examples of efficiency increase in mission critical and business critical industries. Basic technologies and emerging trends in sustainable mobility.

Exam: The final evaluation consists of an oral presentation on a selected topic (related to the course content), and its discussion.

Operational Research

Basics of reliability engineering

Teacher: Matteo Brunelli
ECTS: 2
Content: The students will familiarize with the basic concepts of reliability engineering. At the end of the course they will be able to calculate the failure probability and assess the reliability of any complex system made of a number of components. Therefore, they will be able to assess the reliability of a system and the possible effect of its failure. The following topics will be presented and discusses:

- Probability theory, conditional probabilities, Bayes' rule
- Probability distributions and risk
- Fault trees, minimal cut sets, failure probabilities
- Approximate formulas
- Importance measures (e.g., Fussell-Vesely)
- Concepts of preventive maintenance

Exam: Oral exam.

Industrial planning for production systems

Teachers: Francesco Pilati
ECTS: 2
Content: The objective of the course is to provide PhD students with the necessary competences for the design, installation, and management of industrial plants in order to maximize their technical and economic performances using appropriate mathematical models. Starting from the analysis of the target market, the course analyzes the choices dealing with the economic evaluation of the entire initiative as well as the development of alternative configurations for the production system. A teamwork will be organized where the students will be able to try their hand at the practical application of the learned notions to quantitatively solve a company-derived industrial plant problem.
In particular, the following topics will be covered in the lectures offered fully online with live streaming:

- Introduction to industrial plants.
- Analysis of market demand and quantitative methodologies for its forecasting.
- Linear regression and correlation between market demand and economic indicators
- Classification of costs for industrial plants: fixed and variables.
- Influence of time on fixed costs: depreciation.
- Criteria for assessing the profitability of industrial investments: NPV, IRR, PAYBACK.
- Analysis of the final product and production quantities of an industrial plant.
- Classification of machines and operators categories for industrial plants.
- Mathematical models for determining the number of machines in production systems.
- Mathematical models for determining the number of operators in production systems.
- Quantitative techniques for production leveling.
- Calculation of the stage potential for the different production process phases.
- Determination of the space required for the production activities of an industrial plant.

Exam: The final examination of the course is defined by a technical written report and an oral presentation performed live online of the teamwork developed by the students.

Introduction to performance evaluation and data envelopment analysis (DEA)

Teacher: Debora Di Caprio
ECTS: 2
Content: To improve performance, organizations need to constantly evaluate operations or processes related to products, services, marketing, and others. Performance evaluation and benchmarking are widely used to identify and implement best practices able to improve performance and increase productivity, and particularly valuable when objective or engineered standards are not available to determine performance efficiency and effectiveness.
Benchmarks are somehow limited since they work with single measurements that must be considered one at a time. Evaluating the performance of an organization implies dealing with multiple performance metrics that describe a structured operational system. The relationships among the different performance metrics are generally unknown or involve a high degree of complexity that conditions the evaluations.
This course introduces the methodology of data envelopment analysis (DEA) and its uses in performance evaluation and benchmarking under the context of multiple performance measures. DEA uses mathematical programming techniques and models to evaluate the performance of Decision Making Units (DMUs) in terms of multiple performance metrics. Because of its flexibility, DEA can be applied to model operational processes in a large number of research areas, such as education, health care, banking, market research, organization effectiveness, transportation, and manufacturing.
The course will cover the formal background required for the implementation of DEA. Several envelopment models (both input- and output-oriented) will be presented. The shapes of best-practice (or efficient) frontiers obtained from these models can be associated with

the concept of Returns-to-Scale (RTS) which will also be discussed. Examples of efficiency evaluation problems will be simulated numerically.Linear Programming (LP) is one of the most important optimization problems in applied mathematics and engineering. Many practical problems in Operational Research can be expressed as linear programming problems and the impact of LP in economics and business since the end of the Second World War is extremely relevant.
It is now a crucial tool for many companies and other sectors of society. Roughly speaking, LP concerns the general problem of allocating limited resources among competing activities in an optimal way.

Exam: The final evaluation consists in the completion of a project assignment.

Linear and non-linear optimization

Teacher: Matteo Brunelli, Michele Fedrizzi
ECTS: 3
Content: Linear Programming (LP) is one of the most important optimization problems in applied mathematics and engineering. Many practical problems in Operational Research can be expressed as linear programming problems and the impact of LP in economics and business since the end of the Second World War is extremely relevant.
It is now a crucial tool for many companies and other sectors of society. Roughly speaking, LP concerns the general problem of allocating limited resources among competing activities in an optimal way.
Linear Programming is used, for example, to find the best possible solution in allocating resources as energy, machines, materials, money, personnel, space, time, etc. , to achieve maximum profit or minimum cost.
Application fields include: planning, production, manufacturing, transportation, technology, finance.
Typical problems solvable by Linear programming techniques are:

- Minimization of production costs;
- Manpower planning;
- Scheduling;
- Portfolio Optimization;
- Vehicle routing;
- Network flows;
- VLSI chip board manufacturing;
- Machine learning;
- Control system design.
- Topics of the course are:
- An overview on various LP problems;
- Graphical solution of two-dimensional problems;
- Fundamental theorem of LP;
- Sensitivity analysis;
- Simplex method;
- Duality;
- Complementary slackness theorem;
- Introduction to Nonlinear programming, Karush - Kuhn - Tucker
- conditions.
- Formulating and solving optimization problems with a modelling language (AMPL)

Exam: Written final exam.

Multicriteria and Multiagent Decision theory

Teacher: Silvia Bortot, Ricardo Alberto Marques Pereira
ECTS: 3
Content: The course intends to provide an introduction to the structure of the aggregation and representation of preferences in the context of multicriteria and multiagent decision theory. The contents of the course are relevant in various areas of applied science and engineering such as decision support-systems, operational research, management and systems engineering.
The course is divided into two parts.
In the first part, we will consider aggregation in the context of multicriteria decision making, considering weighted averaging, ordered weighted averaging, and the general form of Choquet integration. We focus on the interaction pattern among criteria and the way that is expressed by the Choquet capacity of the aggregation model.
In the second part, we will consider the context of multiagent decision making and the dynamic DeGroot aggregation models, with elements of linear algebra, stochastic matrices, and Markov chains. We discuss representation and convergence issues in those models, focusing on the interacting network of decision makers and the nature of the aggregated or consensual opinion.
Exam: Written final exam, involving both theory and exercises, in which the student is assessed on his/her knowledge and understanding of the topics covered in the course.

Project management

Teacher: Andrea Molinari
ECTS: 3
Content: The course provides an overview of project management concepts, theories and techniques, discussing the importance of project definition and presenting fundamental planning and scheduling techniques useful for project managers, such as work breakdown structures (WBS) critical path method (CPM), and Gantt charts. The students will be introduced to the importance of risk assessment within project management, examining important monitoring and control tools and techniques such as earned value analysis and milestone trend charts. Finally, the course will present some Enterprise Project Management (EPM) software tools that help project managers to improve their management activities,

specifically in complex, distributed contexts. The course will have a practical approach, using lab sessions and project management software to explain the theoretical concepts.
This "Hands on" approach to PM tools aims to stimulate further reading and close examination of topics.

- Project management introduction
- PM standards: PMBok overview
- Work breakdown structures (WBS)
- Critical path method (CPM), and Gantt charts
- Scheduling
- Time and cost management
- Risk assessment within PM
- Monitoring and control tools and techniques (e.g. earned value
- analysis)
- Closing a project
- Change and project management
- Controlling distributed projects
- PM, social interaction and PM 2.0
- Software tools for managing projects (EPM)

Exam: Written exam.

Simulation of production and logistics processes

Teacher: Francesco Pilati
ECTS: 2
Content: The objective of this course is to provide students with the necessary competences to simulate production and logistics systems. Advanced simulation techniques are prosed to let the students design and manage such systems through a dynamic evaluation over time of their functioning through the adoption of professional software and tools, with a particular focus on the logistics and material flows.
Digital twins for the layout of considered production system are developed to latter compare and validate different scheduling algorithms and strategies through multi-scenario analysis. Proper key performance indicators are defined to automatically and quantitatively evaluate the performances of production systems monitored over time.
Exam: Project in group of students.

Web strategy

Teacher: Luisa Mich
ECTS: 2
Content: The course looks at the Internet and the World Wide Web in the context of the definition of a web presence strategy for a company or organization. It provides a comprehensive understanding of how to use web technologies and tools to support business goals with an effective web presence strategy. A conceptual framework is introduced to represent and design a web presence strategy in a systematic way.
The course is structured in two parts. The first part gives an overview of the Web development and its technological building blocks and standards. The main topics of the second part are: web business models, web reputation, web presence, website quality, the importance of the web for your career. A few other topics will be illustrated to expose students to the most recent developments of the Web; among them: the Internet of things, cloud computing, QR codes, near field communication.
Exam: A written report is required for the evaluation; students have to apply the web presence framework to a real case.

Multidisciplinary Research Tools and Languages

Design of experiments and analysis and modelling of experimental data

Teacher: Paolo Bosetti
ECTS: 3 + 3 (lab.)
Content: The aim of the course is to illustrate the basic mathematical and software tools for an effective and optimal design of experiments, and for the analysis and modelling of data obtained by the experiments, particularly considering the effect of stochastic behaviour of real systems on the collected data.

Theory (3 credits):

- Recollection of principles of descriptive statistics
- Inferential statistics: Hypothesis testing (X2-test, t-test on the mean, X2-test on the variance, z-test of the comparison of means, F-test for the comparison of variances, paired and unpaired t-test for the comparison of means, Chauvenet criterion, Tukey's test, Shapiro-Wilk normality test), quantile-quantile plots, operating characteristic curves
- Linear regression, linear models, and analysis of variance (ANOVA)
- Design of Experiments: factorial plans, blocking, fractional factorial plans, analysis of factorial plans, model adequacy checking
- Response Surface Methods and Process Optimization

Experimental application (3 credits):

- Usage of GNU-R for experiments design and data analysis
- Design of a factorial plan
- Collection of experimental data
- Analysis of results

For all the above topics, calculations will be illustrated and carried out by using appropriate numerical tools, which will be discussed in the course (Excel Data Analysis Tool, Maple 11/Mathematica, R, etc.).

Exam: Some written exercises to be solved in the classroom for the topics of the first part.
Homework and possible oral discussion for the topics of the second part.

Multidisciplinary integrated design project

Teachers: Davide Brunelli, Devid Maniglio, Lucio Pancheri
ECTS: 3 + 6 (project)
Content: In this course, PhD students employ the knowledge gained during their previous studies to develop a solution and demonstration of a multidisciplinary engineering problem which involves competencies of mechanical, control, electronics, smart materials and biomedical engineering.
At the beginning of the course a number of project ideas are proposed by the teachers and the students are grouped in Project Teams composed by 2 to 4 persons. The domain of the proposed project is primarily in the field of novel electro-mechanical actuators, sensors or biomechanical systems. For example, actuators or sensors based on stimuli responsive polymers (e.g. electroactive, thermo-active, pH responsive, …)
The Project Teams are asked to develop fully integrated prototypes and arrange simple experiments to assess their performance. The course culminates in a presentation of the final designs to an invited audience of faculty members.
Teachers provide initial lectures to provide the basis required to face the proposed technical program, and are involved as mentors during the project phases of design, prototyping, fabrication and testing.
At the end of the course, students are encouraged to write a publication on their work which they can submit to a conference or journal.
Exam: Written report and oral presentation of the project.

Virtual instruments for data acquisition and signal analysis

Teacher: David Macii
ECTS: 3
Content: The objective of this module is to provide students with the know-how to develop software applications for data acquisition, signal processing and instrument control based on LabVIEW™, i.e. the graphical programming language by National Instrument. The course does not require any previous knowledge of the programming environment and it could be useful for Ph.D. students that need to implement automated experimental setups where multiple measurement instruments have to be properly coordinated to collect and to process multiple sensor data.
The course will consist of some theoretical lectures, PC programming sessions and some lab experiments. More specifically, the course covers the following topics; - Introduction to Labview: structure of a virtual Instrument (VI), data types and debugging tools; - Loops, timing and data structures; - Decision making structures, modularity, variables and sequential programming; - Architectural and functional breakdown of data acquisition systems. - Input connection modes, triggering conditions and data acquisition modes; - Measurement uncertainty sources and visualization issues; - Development of VIs for data acquisition, signal generation and I/O interfacing with general-purpose measurement instruments.
Exam: The final exam will consist of a project on selected topics and a short presentation of the main results.

Academic Writing for the Sciences and Engineering

Teacher: Felicity Anne Hope
ECTS: 2
Content: The course aims to extend doctoral students' knowledge of grammatical, lexical, and textual features of written English in an academic context and to provide them with tools to help them become increasingly autonomous writers of their own research in English.
This course examines the main characteristics and genres of academic writing in the sciences and engineering, with a special focus on journal papers. It focuses on identifying the purposes of specific types of writing, meeting the expectations of target readers, drafting and revising texts, and constructively criticising the writing of others.
Four texts will be produced:

- a biographical statement
- an abstract
- a mini literature review
- an article introduction

Specific topics to be addressed include:

- analysing genres to identify audience, aims, and patterns of organization
- understanding and avoiding unintentional plagiarism
- improving academic style: register, citation, mechanics, and punctuation
- writing effectively: achieving clarity through choice of grammatical subject and of verb, effective placement of information within sentences.
- hedging, boosting, and emphasizing claims
- referring to equations, figures, and tables
- grammar issues such as use of articles, word order, tenses, participle clauses, noun phrases, relative clauses and parallel structures
- improving lexical range and accuracy
- developing paragraphs and structure
- constructing self-editing checklists
- resources and tools for academic writing

An active approach is used, with participants drafting, discussing, and revising short texts related to their academic work. Lessons consist of a mixture of teacher explanation, practice exercises, and class/group discussion of participants' own writing. At the start of the course participants are required to complete the Self-Paced Course on Academic Writing on didatticaonline.unitn.it/postlaurea. This consists in 5 modules covering basic principles of effective writing.

Exam: Students are required to complete the Self-Paced Course on Academic Writing at the beginning of the course. During the course students are required to complete 4 short written texts, and to revise them to a publishable standard. Texts are evaluated at C1 level. A minimum of 60% is required on the total score for coursework. A minimum of 75% attendance is required.

Academic Writing II (Sciences and Engineering)

Teacher: Felicity Anne Hope
ECTS: 2
Content: The course aims to revise and extend students' ability to use the language and writing skills introduced in the Academic Writing for the Sciences and Engineering course, and to provide support in improving a text they are currently writing, focusing on accuracy and clarity. Particular attention is given to the writing of a literature review.
The course is open to students who have passed the Academic Writing for the Sciences and Engineering course (or an earlier version of the course, Technical English or Scientific English).
The course will revise particular problem areas of grammar such as

- Topic – stress positions in a sentence
- Use of articles
- Position of adverbs
- Tenses
- Participle clauses
- Noun phrases – choosing between compound nouns, gerunds, 'the – of', genitive structures
- Relative clauses and reduced relative clauses

A substantial part of the course is devoted to language issues arising from students' texts and to consolidating strategies for editing one's one work.
An active approach is used, with students bringing texts they are writing as part of their academic work and then correcting them individually and as a group. Texts may be a thesis proposal, research paper or an extract from a draft thesis.

Exam: 75% attendance is required.
Students are required to bring, and then correct, 2 texts or text extracts and to participate actively in class sessions.

Entrepreneurship and Innovation

Teacher: Marco Masia
ECTS: 3
Content: The course aims to provide an introduction to the concepts of innovation and entrepreneurship throughout an exercise simulating a venture creation from idea to pitching to other stakeholders. "Venture" is hereby intended both as for-profit and not-for-profit organization. Using a challenge-based problem-solving approach, the course trains students to use their knowledge and background to settings unfamiliar to them. They will be split in teams (the most diverse possible in terms of gender, discipline, etc.) and will work on different facets of venture creation throughout the workshop. When they present the results of their

teamwork after each breakout, they are asked to comment on other teams' presentations too. With this course, students will get acquainted with concepts related to start and run a venture and will develop new entrepreneurial competences in the framework established by the Joint Research Center in 2016.
Subtopics:

- Basics of innovation and entrepreneurship
- Creativity
- Hypothesis driven entrepreneurship
- Managerial accounting
- The business model canvas
- Innovation funding: private and public opportunities
- Strategy and competitive advantage
- Basics of persuasive communication
- Pitching

Exam: Students will pitch their venture idea and be assessed throughout the programme for their individual participation and work in a group. They will also peer review each team presentations and provide feedback (individual).

Presentations for the Sciences and Engineering

Teacher: Felicity Anne Hope
ECTS: 2
Content: The course aims to give both inexperienced presenters and those with some presenting experience an opportunity to develop their presentation skills and to have feedback on their use of English while presenting. An active approach is used, with students giving presentations on topics related to their research, and giving feedback to others on presentation skills.
Students should already have a B2 level of English.
The following subjects will be introduced:
What makes a good/bad presentation – discussion and examples.
How to be easy to understand.
Student presentations, followed by feedback on presentation skills and on use of grammar, vocabulary and pronunciation.
After an introductory session on presentation skills, most of the course consists of student presentations and follow up discussion of the presentations seen. Language-related feedback is given by the teacher. Exercises to work on specific language-related issues may be suggested, or may be incorporated into the class if appropriate.
Exam: Students are required to complete at least one presentation that is generally comprehensible to the group. A minimum of 75% attendance is required.

Internationalisation

The Doctoral School is strongly engaged in pursuing and increasing the international aspects of its education and research. Doctoral students are strongly suggested to spend a research period abroad.
Furthermore, the School has signed bilateral agreements to enable exchanges of professors and students and to issue double-degrees.

Co-tutelle agreements

Co-tutelle agreements allow Doctoral students to achieve a double or joint degree as a PhD, by the preparation of a Doctoral thesis both at the University of Trento and at a partner university. The Doctoral thesis will be discussed at only one university and will be elaborated with the advice of two thesis supervisors. So far, co-tutelle agreements are running with the University of Colorado at Boulder (USA), the University of Texas at Arlington (USA), Virginia Commonwealth University (USA), the Institut National des Sciences Appliquées (INSA) of Toulouse (France), the Universidade Federal de Santa Catarina (UFSC, Brazil), the Lappeenranta University of Technology (Finland), the Norwegian University of Science and Technology (NTNU, Norway), the Amrita University (India), the University of Maastricht (Holland).

How to start:
A Doctoral co-tutelle is based on a preliminary, intergovernmental or bilateral output agreement between two universities.
Within the framework of the official agreements mentioned above, "ad personam" agreements are made for each Doctoral student between the Rectors of the universities involved.
It is also possible to arrange for co-supervision of a thesis with a university not mentioned above. In this case, an "ad personam" agreement is signed between the Rectors of the two partner universities.
The agreement must include:

1) the title or the subject of the thesis;
2) the names of the two supervisors (one for each partner)
3) the duration of the research period to be spent at the partner university
4) the appointment of the Final Examination Committee

Student services, benefits and other information

N.B. All information is updated October 2023; it is advisable to check further news on the website.

Canteens

In Trento there are six university restaurants run by the *Opera Universitaria*: two in the city center (T. Gar and XXIV Maggio), one in Rovereto, one in Mesiano and two in Povo (one at the Department of Science and another at the "Polo F. Ferrari"). There are also three coffee bars: one at the Department of Engineering in Mesiano, another at the "Polo F. Ferrari" in Povo, and finally the UniBar at the San Bartolameo Student House (via Malpensada, 138)**.** There are three different menu offers: **one full meal** (4,90 €), **one lighter meal** (4,40 €) and **one 'Menu Snack'** (3,10 €).

University restaurants are open from Monday to Sunday, with alternative work shifts on Fridays, Saturdays and Sundays.

Doctoral students can access the university canteens with their **student's card**.

The students with food allergies and intolerances can ask the checkout clerks in order to have information about the menus suitable to their needs.

Further information at:
https://www.operauni.tn.it/en/canteens

Computer services

Students are provided with a place to work with computer equipment required. At the Department of Industrial Engineering an IT Centre is in charge of the services related to: mail account, wireless, networking, etc.

Disabled persons: services

These services are organized by the *Opera Universitaria*. Students who want to make use of these services must make a request when enrolling, by filling in the forms. The specialized tutoring activity of the disability service is carried out in collaboration with disability delegates who are present in the various faculties.

The main activities and services:

- Welcoming;
- Projects for the national voluntary service;
- Economic support;
- Personalized accommodation;
- Personalized transport and assistance;
- Representative lecturers;
- Educational aid.

For detailed information about each service visit the *Opera Universitaria* website: http://www.operauni.tn.it/home

Erasmus

Doctoral students can apply for Erasmus scholarships for study and/or Placement (which are compatible with the Doctoral ones).
Details and info at:
http://www.unitn.it/en/outgoing/22368/llperasmus-studio

Extra-curricular activities

Students who intend to carry out extra-curricular activity must ask for the authorisation to the Director of the School. Extra-curricular activity includes limited external work, paid collaborations, supplementary educational exercises and tutoring. In particular, as far as supplementary educational exercises within courses offered by the University of Trento, in the academic year 2023/2024 the teaching board might consider requests up to 80 hours, of which maximum 40 hours of type A, upon approval of the supervisor.
Students must ask for the authorization also for external activity done for free, as it may be incompatible with the Doctoral programme.
Students are warned that unauthorised external activity may result in the exclusion from the School.

Fellowship

Fellowships are awarded after a comparative evaluation and on the basis of the list of applicants given in order of merit; all other conditions being equal, the economic situation of the candidate will be considered in accordance with the Decree of the President of the Italian Republic, 9th April 2001.

Fellowships cannot be combined with other grants, except those awarded by national or foreign scientific institutes for periods spent abroad which are considered useful for the student's research activities.

If a Doctoral student has already been awarded a grant in the past (even for one year only) for a Doctoral course in Italy, s/he cannot receive a Doctoral scholarship again.

Scholarship payment: scholarships are normally paid in instalments every two months in advance. The scholarship can be confirmed for the following year if all prerequisites are fullfilled.

Scholarship renouncement: Doctoral students who decide to renounce to their scholarships have to fill in the specific form so to communicate their decision to the School and to the Doctorate Office of Science and Technology

50% scholarship increase

Doctoral students are entitled to get a 50% increase of their fellowship when staying abroad for reason related to their Doctoral research activities and studies.

The increase of the scholarship can be allocated to students with fellowship till the end of their third year. So, they are not entitled to get the increase of the scholarship for the research period spent abroad after the 31st of October of the third year or during the year of extension.

Before leaving Doctoral students have to send or bring the following documentation to the School and to the Doctorate Office of Science and Technology: the form to apply for the increase of the scholarship; the authorization of the Director of the Doctoral School for a research period not exceeding the 6 months or copy of the Doctoral School Committee's resolution for a period lasting more than 6 months.

Note that the Director will authorize the increase of the fellowship ONLY for periods spent aboard lasting a minimum of 1 month and ONLY for research activity; educational activities carried out abroad can only benefit of the mobility reimbursement. In any case, the Director of the School will authorize to spend a period abroad only if the Supervisor/s has/have already signed the request.

At the end of the period abroad, once back at the University of Trento, Doctoral students have to provide the Doctorate Office with a certificate showing their date of arrival and their date of departure, issued by the foreign Institution, as the scholarship's increase is daily calculated. Note that the certificate's date must be subsequent to the final date of the period spent abroad.

The grant's increase is generally paid at the end of the period spent abroad. However, for stays abroad lasting 3 months or more, the University can pay 60% of the entire increase in advance and the remaining 40% when Doctoral students are back. In this case, the Authorization and the Application form for the 50% increase must be sent or taken to the Doctorate Office of Science and Technology at least 2 months before leaving.

Details and info at:
http://www.unitn.it/en/servizi/1937/Doctoral-scholarships

Opera's scholarships

Doctoral students who have not been assigned a Doctoral scholarship can be assigned an *Opera Universitaria* scholarship according to specific prerequisites. Further information can be found on the *Opera website.*

Health insurance

Non-EU citizens
Health insurance for Italy has to satisfy the following requirements:

- it must cover expenses in case of emergency treatment and urgent hospitalization (recovery in casualty);
- it must cover the entire duration of the stay in Italy;
- it must guarantee the policy-holder's return to his/her own country in case of serious illness;
- it must be in English or translated in Italian and legalized by the Italian Embassy/Consulate;
- it must also be valid in the Schengen Area.

In order to get a study visa students have to demonstrate to the Italian diplomatic Representative that they have a health insurance coverage fulfilling the above requirements. We suggest to buy one with at least 3-6 months' validity. Once arrived in Italy, students can enrol to the National Health System at the cost of € 149,77/calendar year. If students have family members with them or they get revenues beside the study grant, they should contact the Welcome Office before paying.

Double citizenship (Italian): students who are going to transfer their permanent residence in Italy can benefit of free enrollment in the Italian National Service. In this case, they must go to the Local Health Board with their Italian passport and the receipt proving that they have applied for residence in Italy.

If there are bilateral agreements between the student's home Country and Italy (such as Argentina, Australia, Bosnia-Erzegovina, Brasil, Cape green, Croatia, Kosovo, Macedonia, Montenegro, Principality of Monaco, Republic of San Marino, Serbia, Tunisia, Vojvodina, etc.) and students are entitled to health coverage in your country, BEFORE leaving for Italy they should get the specific form for the extension of the coverage from their country to Italy and take this form to the Local Health Board in Trento in order to receive the declaration for health coverage in Italy. It is their responsibility to get all information about bilateral agreements from the Italian diplomatic representatives abroad and from the competent health Institution in their home Country.

EU citizen
Before leaving for Italy, students have to go to the competent Health Institution in their Country in order to ask for an extension to Italy of their health assistance through one of the following issues:

- E 106 or E 109 Form (the latter in case the student was in charge of her/his parents) for study or work stays **more than 365 days**. This gives the students the right, once they have submitted to the Health Local Board in Trento, to the same cares one benefits with the enrollment to the Italian Health System.
- the European Health Insurance Card (so called "TEAM Card") for temporary stays (up to 365 days), by which students are automatically covered in all EU-member countries or health cares considered as "necessary". The TEAM Card does not cover in any way the "planned health cares" (e.g. non urgent tooth cares, thermal treatments, etc.).

The Team Card is not considered enough for the registration at the Comune, procedure compulsory by law after 90 days of uninterrupted permanence in Italy (see article 9 of Ministerial Circular of 18th July 2007).
As an alternative, students will have to draw up a private health insurance which covers all risks (maternity included). It is not possible to enrol at the Italian Health Service (see art. 7 of Dlgs n 30, 7th February 2007).

For all students
Valid only for Trento and only during academic activities for which the person insured is in Italy, or during a journey or assignment outside Trento (authorized by the responsible professor). The University of Trento provides health insurance coverage to its students only in the case of hospitalization due to an accident (INA Assitalia). It also provides coverage for injuries suffered by the student for which the University is responsible. The insurance also covers damage that students may cause to other people, things or animals at the University (Lloyd's of London).

Laboratories and other facilities

Doctoral students are allowed to use all the facilities and the laboratories at DII (http://www.unitn.it/dii). Safety in the Laboratory Courses (basic and advanced) are compulsory to access the laboratories activities.
In order to access the Department on Saturdays and festive days, students will have to fill in an authorization form at the Secretariat.
Laboratories: due to security laws into force, the access to the laboratories will be allowed only if the specific regulations will be undersigned (accepted) by the student.

Language courses

Doctoral students can attend language courses organized by CLA-Language Centre. CLA has a wide educational offer which include extensive and intensive courses of English, French, Spanish, German, Chinese and other languages, included Italian for foreigners.
Foreign students are requested to gain a basic knowledge of Italian during the Doctoral programme. This is in order to reach a certain level of competence so that they may consequently be integrated in an Italian working environment.
In order to enrol, Doctoral students must pass the online test and pay a € 50,00 fee.
A specific course in Technical English for engineers, which is compulsory, will be organized by the School, free of charge.

Details and info at:
http://www.unitn.it/en/cla

Library

The University of Trento has several libraries, each specialized in a specific discipline. At the Department of Industrial Engineering a rich collection of

journals, books, etcetera is available to Doctoral students who will be provided with a card which will allow them to borrow books.

Sport

CUS, the University sports centre, promotes sport activities in the University community, such as sailing (also for disabled students), windsurfing, canoeing, boat racing, skiing, aerobics, aqua gym, tennis, basketball and gliding. It also offers students special discounts on the access to swimming pools and gyms; CUS organizes sport events like the "Facoltiadi" and interfaculty competitions. CUS is provided with three sport centres meant for basic activities and for competitive sports such as: baseball, basketball, boat racing, Nordic skiing, cross-country, tennis and triathlon. Further info at the CUS website: http://www.unitrentosport.unitn.it/

Transport

Doctoral students can benefit from "free circulation" yearly pass for in-town and out-of-town public transport. Further info in the Scholarship section at: https://infostudenti.unitn.it/en/free-circulation-pass-town-and-out-town-public-transport

Bus

A single ticket costs € 1,20 and is valid for 70 minutes. Always buy tickets before getting on the bus. In case of necessity, you can buy on board a ticket for a single bus trip at the cost of € 2,00. If you have a bus pass ("Smart Card"), you have to pass it through the machine every time you start a new travel. A penalty is foreseen if you do not do it and if you travel without ticket.

Rent a bike

There are **250** bikes of the *Opera Universitaria* at students' disposal. The Doctoral students, the researchers, the professors and the lecturers of the University of Trento and all the other users authorized by the *Opera Universitaria* should pay € 5,00 every month for the bike. Everyone has to give security for € 60,00. You will also have a monthly routine maintenance.

For further information and if you want to download the form, please visit the *Opera Universitaria* website.

Travel expenses

Before leaving: students must fill the "Authorization" form (available online, install the widget Gestione Trasferte).
During the travel: be careful and do not exceed the maximum expenses allowed for Doctoral students (read the mobility regulations) and keep all the tickets, receipts, invoices etc.
Upon return: fill the "Reimbursement" on-line form, attach all the original tickets, receipts etc., sign the form and deliver it to the Secretariat.
The reimbursement form must be delivered as soon as possible, immediately after the return. For reimbursements exceeding the amount of 77,47 euros a revenue stamp (*marca da bollo*) of 2 euro is required.

Registrations to conferences, workshops, etc.: a special form is to be filled BEFORE registering to conferences, seminars and so on, in order to allow our Administrative secretariat to pay the fees in due time. Should students have no time to ask the registration trough the administrative office, in order to get the full refund of the amount they will have to ask to the secretariat of the conference the release of an invoice (ask for the data to the Secretariat of the School).

N.B.: students who are going abroad to spend the authorized research period and who have obtained the increase of the scholarship can ask only for the reimbursement of travel expenses, as the amount of meals and lodging is to be paid with the increase.

Visa and stay permit

The visa, issued by an Italian diplomatic representative abroad, entitles non-EU citizens to enter into Italy. There are several types of visas.

The stay permit is the document issued by the Police Headquarters in the town where you live which entitles you to temporarily live in Italy. Non EU citizens must start the procedure to request it within 8 working days from their arrival in Italy; EU citizens must start the procedure to ask it after having spent 90 days (without any interruption in between) in Italy.

Regulations are strict, so please refer to the Welcome office for further information and stick to it.

Rights and duties of Doctoral students

From University Regulations for Doctoral Programmes:

https://www.unitn.it/alfresco/download/workspace/SpacesStore/5d57e9a3-af73-445d-a5a9-e779ed1cb3fb/University_Regulations_for_Doctoral_Programmes_finale%20(1).pdf

Art. 25 – Right and duties of doctoral students

1. Admission to the Doctoral Programme entails an exclusive full-time commitment.

2. Students enrolled in a Doctoral Programme must undertake to attend the courses, seminars, lessons, and to carry out research and study activities in the structures designated for these purposes and to submit a report on the research done to the Doctoral Programme Committee at the end of each year of study. Following a positive evaluation as per Art. 12, par. 8, letter m) by the Doctoral Programme Committee, students must register for the following academic year and/or send the request to be admitted to the thesis review process by the deadline set and communicated by the offices in charge and posted on the University website, to avoid forfeiture, and the resulting termination of the students' enrolment, unless there are documented reasons.

3. Students are expected to behave according to the Code of Ethics of the University and to the Student Honour Code. In addition to these Regulations, specific rights and duties of Doctoral students can be found in the Internal Regulations of each Doctoral Programme as specified in Art. 8 par. 2.

4. The Doctoral Programme Committee may decide to exclude Doctoral students from the Doctoral Programme with the resulting forfeiture of the scholarship in the following cases:

a) insufficient results in the assessments during the year;

b) negative opinion given by the Doctoral Programme Committee regarding admission to the subsequent year of study; to this end, the Doctoral Programme Committee will verify the achievement of the results required for the current year as well as the assiduousness and commitment demonstrated by the student in the research work;

c) the student has accepted employment contracts without the prior authorization of the Doctoral Programme Committee;

d) unjustified and prolonged absences or prolonged unavailability.

5. The Doctoral Programme Committee can exclude a student, with the resulting forfeiture of the scholarship, also based on specific provisions expressed in the Internal Regulations of the Doctoral Programme. Within the Industrial Doctoral Programmes, the enrolment of a Doctoral student on the Doctoral Programme ends if his/her working contract at the company terminates.

6. The Doctoral student has the right to obtain leave for maternity/paternity, for serious and substantiated illness or to attend training for the qualification to teach in Italian schools.

7. The maternity rules as per Decree of the Ministry of Labour and Social Welfare, 12.07.2007, published in the Official Journal no. 247 of 23.10.2007 are applied to Doctoral students.

8. A Doctoral student may suspend their enrolment in the Doctoral Programme for a maximum of six months on request, subject to

authorization by the Doctoral Programme Committee, for serious and documented personal and family reasons.

9. At the end of the suspension period, the Doctoral student will resume attendance of the Programme by submitting a declaration signed by the Director of the Programme. The administrative deadlines and the payment of the scholarship - if the student is scholarship-assisted - will be postponed for a period equivalent to the absence. The Doctoral Programme Committee will approve a programme for completion the training activities; however, under no circumstances can the official duration of the Programme be shortened.

10. For suspensions lasting more than thirty days or in case of forfeiture or exclusion from the Doctoral Programme, payment of the scholarship is stopped.

Student disciplinary procedures

If at any time during the course of the programme the Supervisor has concerns about progress, s/he should inform the student in writing.
If the unsatisfactory situation continues, the Supervisor should inform the Director of the School, who will decide the actions to be undertaken.

At any moment, if there is documented proof that the student was negligent or neglectful in his/her studies, the School Teaching Board can suggest the Rector of the University of Trento to exclude him/her from continuing the Doctoral course.

Any behaviour implying the violation of the laws will be reported to the competent public Office.

Student complaints procedure

If at any stage throughout the period of study problems should arise between the student and the Supervisor (the student feels that the standard of supervision is inadequate or that s/he is unable to establish effective working relationships with the Supervisor, etc.), the student must contact immediately the Director of the School in order to find a solution.

The School Teaching Board can remove the Supervisor from her/his responsibility whenever s/he does not fulfill her/his obligations.

Abandonment, suspension, exclusion

Abandonment

Doctoral students can abandon their studies at any time, by filling in the form and sending it to the Director of the Doctoral School and to the Doctoral studies office. After quitting their studies, Doctoral students no longer have the right to receive their scholarship.

Suspension

Doctoral students have the right to suspend their studies in case of:

- maternity;
- serious and certified illness;
- military service.

Absence due to reasons other than the ones listed above must be explicitly authorized by the Doctoral School Committee. If Doctoral students fail to attend their Doctoral course for more than 30 days, their scholarship payment will be suspended.

Exclusion

The Doctoral School Committee may decide to exclude students from the Doctoral School in the following cases:

- negative opinion given by the Doctoral School Committee regarding admittance to the following year;
- if students accept to carry out professional services without the Doctoral School Committee's authorization;
- unjustified and long absences;
- any reason specifically expressed in the Doctoral School's rules and regulations policy.

Contact information

Doctoral Programme in Materials, Mechatronics and Systems Engineering
c/o Department of Industrial Engineering
Via Sommarive, 9
I-38123 TRENTO
ITALY

Website: http://www.unitn.it/en/drmmse
Secretariat:
dott.sa Alice Aste
Tel. +39 0461 282401
e-mail: dii.phd@unitn.it

Reference offices

Opera universitaria: http://www.operauni.tn.it/home

Doctorate Office - Scientific Area
Via Sommarive 14 – 38123 Povo, Trento
Tel. +39 0461 28 2194/3909/5332/5233
phd.office-st@unitn.it
Opening times: Mondays, Wednesdays and Fridays: 10:00 - 12:00

- collaborating in planning and programming Doctoral courses at a national and international level;
- carrying out organization activities related to Doctoral courses (agreements editing, call for selections issuing, organization of applications, organization of call procedures);
- managing the procedures related to Doctoral students' careers (enrollments, moving on to following years, certifications, etc.);
- organization of procedures and accounting aspects related to scholarships, accommodation benefits, scholarship rises and fee payment (TDS);
- supporting the participation in internationalization activities promoted and encouraged by MIUR and MAE and organization of relations with the Ministries and Embassies;
- management of the supporting information system (data banks, Doctoral courses register office);
- collaborating with Doctoral course coordinators and the NdV for the editing of the proposals and annual reports of the Doctoral courses;
- national licensing examinations management: management of applications, support to the committees, relations with the Ministry and the professional orders;
- coordinating the arrangement of the forms and information material for users.

International Mobility Office – Science and Technology Area (Welcome office)
Via Sommarive 5, 38123 Povo, Trento
Tel. +39 0461 28 3240/3980/3236/3237/1864
welcome@unitn.it
Opening times: Mondays and Wednesdays: 10.00 -12.00.

- organization and management of pre-welcoming services addressed to incoming international students/scholarship holders;
- assistance and support to international students/scholarship holders in carrying out all the procedures necessary to regulate their stay and use University and non-university services;
- planning and organization of events, information sessions, multicultural activities and activities to be included in University and theterritory;
- management of the enrollment procedures for foreign students (pre-enrollment, qualification verification, Italian language test, matriculations);
- Fulbright window and support in organizing agreements with the Committee for cultural exchanges between Italy-Us.