UNIVERSITÀ DEGLI STUDI DI PADOVA

INDUSTRIAL ENGINEERING

Course unit English denomination	**Advanced methods for fatigue design**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2-3 year February
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to fatigue assessment of mechanical components in presence of cracks or notches. Derivation of stress fields ahead of cracks/notches: Airy stress function and complex potential function method (Kolosov and Muskhelishvili). Case study: sharp V-notches under in-plane loading. Lazzarin-Tovo analytical derivation of local stress field based on complex potential functions and comparison with Williams' solution. Definition of Notch Stress Intensity Factors (NSIFs) and introduction to local approaches based on NSIF-concept: averaged strain energy density (SED) and peak stress method (PSM) Practical application of local approaches to fatigue strength assessment of mechanical components by means of FE analyses (Ansys FE code).
Learning goals	Students will learn the analytical basis of the notch stress analysis Students will learn how to apply standard approaches (e.g. nominal stress) and local approaches (NSIF, SED, PSM) for the fatigue strength assessment of welded joints Students will learn how to perform a linear elastic structural FE analysis by using Ansys code.
Teaching methods	Students will learn the analytical basis of the notch stress analysis

	Students will learn how to apply standard approaches (e.g. nominal stress) and local approaches (NSIF, SED, PSM) for the fatigue strength assessment of welded joints Students will learn how to perform a linear elastic structural FE analysis by using Ansys code.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Structural/Solid mechanics course
Examination methods (if applicable)	Final evaluation will be based on a home assignment
Suggested readings	- Sadd M. H. Elasticity. Theory, Applications and Numerics. Elsevier; 2004. - Lazzarin P., Tovo R. A unified approach to the evaluation of linear elastic stress fields in the neighborhood of cracks and notches, Int. J. Fract. 78 (1996) 3–19. - Anderson T. L. Fracture Mechanics. Fundamentals and Applications. CRC Press; 1995. - Lazzarin P., Zambardi R. A finite-volume-energy based approach to predict the static and fatigue behavior of components with sharp V-shaped notches, Int. J. Fract. 112 (2001) 275–298. - Meneghetti G., Lazzarin P. Significance of the elastic peak stress evaluated by FE analyses at the point of singularity of sharp V-notched components, Fatigue Fract. Eng. Mater. Struct. 30 (2007) 95–106. - Radaj D, Vormwald M. Advanced methods of fatigue assessment. Springer; 2012.
Additional information	

Course unit English denomination	**Advanced Modeling and Optimization of Multi-Energy Systems for a Decarbonized Future**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	1-2-3 year
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes(Attendance is required for at least 2/3 of the lecture hours) ☐ No
Course unit contents	The course addresses the main issue of optimally integrating new renewable energy units into currently available energy system and networks to push towards a decarbonized future. It focuses on the concept of “Multi-Energy Systems” (MES), in which different energy carriers interact with each other to increase the flexibility of the energy system and make it possible to accommodate higher shares of renewable energy. These interactions may take place through many energy conversion, storage, and consumption units. The shift in approach from optimizing individual units as separate entities to optimizing the design and operation of a MES as a whole is pivotal to achieve greener energy systems in the less costly, more efficient and environmentally friendly way. The course is organized into 3 modules of 5 hours and involves lectures in the classroom and practical lessons in front of the computer. 1st Module: Introduction to the concept of “Multi-Energy Systems”. Modeling of MES component, e.g., energy conversion units, storages and energy demands. Derivation of the linear models of the MES components. Basic information about the structure of variables and equations in Python environment. Implementation of the models in Python. 2nd Module: Introduction to engineering optimization and optimization Algorithms. Formulation of the SDO (Synthesis, Design, Operation) optimization problem of MES: deterministic optimization approach, coupling

	between curves of energy demand and availability. Definition of objective functions for maximizing energy saving, cost-effectiveness and environmental benefits. Discussion of applications. 3rd Module: Integration of the models of each MES component into the optimization model of the entire MES. Basic information on the structure of decision variables, constraints, objective functions and optimization algorithms in the Gurobi environment. Examples of design and operation optimization of a MES in Python-Gurobi environment.
Learning goals	Understand the general features of the model of an energy system of any complexity Learn the basics of the optimization of energy systems Learn how to implement optimization models of energy systems in Python-Gurobi environments Critical analysis of the results obtained in the practical implementations.
Teaching methods	Understand the general features of the model of an energy system of any complexity Learn the basics of the optimization of energy systems Learn how to implement optimization models of energy systems in Python-Gurobi environments Critical analysis of the results obtained in the practical implementations.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☐ Yes ☒ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on a home assignment.
Suggested readings	- Bejan A., Tsatsaronis G. & Moran M.J. (1995). Thermal design and optimization. New York: John Wiley & SonsLibro - Rao S.S., Engineering optimization: theory and practice. New York: John Wiley & Sons, 2019 - Ravindran A., Reklaitis G.V. & Ragsdell K.M. (2006). Engineering optimization: methods and applications. John Wiley & Sons - Rech S., & Lazzaretto A. (2018). Smart rules and thermal, electric and hydro storages for the optimum operation of a renewable energy system. Energy, 147, 742-756 - Rech S. (2019). Smart energy systems: Guidelines for modelling and optimizing a fleet of units of different configurations. Energies, 12(7), 1320

Università degli Studi di Padova

INDUSTRIAL ENGINEERING

- Dal Cin E., Carraro G., Volpato G., Lazzaretto A., & Tsatsaronis G. (2025). DOMES: A general optimization method for the integrated design of energy conversion, storage and networks in multi-energy systems. Applied Energy, 377, 124702

Additional information

Course unit English denomination	**Bibliographic resources and research tools for PHD students in Industrial Engineering**
SS	**-**
Teacher in charge (if defined)	Librarians
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2-3 year December – January
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	1st Module (4 hours): - Engineering libraries and their services (local and interlibrary loan, document delivery, bibliographic reference, book purchase proposal…) - GalileoDiscovery as the University of Padua Library Search Tool - Engineering, Economics, Management databases (BSC, IEEE Xplore, Engineering Village, Reaxys, ACM Digital Library, ASTM Compass, DieselNET, Total Materia, BSOL) - Citation databases: Scopus (Elsevier), Web of Science (ISI). - Bibliometric indicators: quality measurements of scientific publication 2nd Module (4 hours, in two lessons): - Academic publishing and Open Access. Padua Research Archive (PRA/IRIS): the institutional repository for academic research. - Open Science and data management. Research Data Unipd, the Institutional repository for the outputs of research. (2 hours) - Bibliographic citations and citation styles. Reference management: introduction to Zotero. (2 hours)
Learning goals	Upon completion of the course, doctoral students will be familiar with the services of the SBA libraries, tools for bibliographic research, and the cycle of scientific publishing, including open science.

Teaching methods	Upon completion of the course, doctoral students will be familiar with the services of the SBA libraries, tools for bibliographic research, and the cycle of scientific publishing, including open science.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final test after online course and after face-to-face course, to confirm the participation and the training.
Suggested readings	- Engineering Central Library – University of Padova website: http://biblioingegneriacentrale.cab.unipd.it/ - University Library System website: https://bibliotecadigitale.cab.unipd.it/en specially about Open Science, Open Access, Open Data, Metrics. . . https://bibliotecadigitale.cab.unipd.it/en/digital-library/about-publishing - The Principles of Open Scholarly Infrastructure https://openscholarlyinfrastructure.org/ - Aliprandi, Simone, and Simone Aliprandi. Fare open access: la libera diffusione del sapere scientifico nell’era digitale. Ledizioni, 2017. - Capaccioni, Andrea, et al. Ricerche bibliografiche: banche dati e biblioteche in rete. 2. ed, Maggioli, 2018. - Turbanti, Simona. Strumenti di misurazione della ricerca: dai database citazionali alle metriche del web. Editrice Bibliografica, 2018.
Additional information	

Course unit English denomination	**Bioelectromagnetics**
SS	
Teacher in charge (if defined)	
Teaching Hours	5
Number of ECTS credits allocated	1
Course period	1-2-3 year April - May
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to bioelectromagnetics. Electromagnetic field coupled with the human body; physical quantities involved. Brief introduction to tissue from the point of view of electromagnetic field coupling. Electrical properties of tissue as a function of the frequency. Protection rules from effects related to electrical and magnetic fields at low and high frequency. ICNIRP and EU regulations. Safety in working and public environments. Typical sources in industrial and public environments. Measurements of the intensity of the magnetic field at low frequency. Effects of electric, magnetic and electromagnetic fields on cells and tissues, e.g. heating and electric stimulation, considering the frequency spectrum of the electromagnetic field: from low frequency to microwaves. Protection rules following ICNIRP rules.
Learning goals	Understanding the mechanisms and effects of the electromagnetic fields on the human body. How are derived the limits.
Teaching methods	Understanding the mechanisms and effects of the electromagnetic fields on the human body. How are derived the limits.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on: multiple choice questionnaire.
Suggested readings	- ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). Health Physics 1998, 74, 494–522. - ICNIRP Guidelines on Limits of Exposure to Static Magnetic Fields. Health Physics 1994, 66, 100–106. - ICNIRP Guidance on Determining Compliance of Exposure to Pulsed Fields and Complex Non-Sinusoidal Waveforms below 100 KHz with ICNIRP Guidelines. Health Physics 2003, 84, 383–387. - ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 KHz). Health Physics 2010, 99, 818-836 10.1097/HP.0b013e3181f06c86. - International Commission on Non-Ionizing Radiation Protection (ICNIRP)1 Guidelines for Limiting Exposure to Electromagnetic Fields (100 KHz to 300 GHz): Health Physics 2020, 118, 483–524, doi:10.1097/HP.0000000000001210. - Andreuccetti, D.; Bini, M.; Checcucci, A.; Ignesti, A.; Millanta, L.; Olmi, R.; Rubino, N. Protezione Dai Campi Elettromagnetici Non Ionizzanti; IROE, 2001;
Additional information	

Course unit English denomination	**Biomedical Imaging with MEMS**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1 year November
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to biomedical imaging techniques MEMS technology for biomedical imaging applications MEMS devices for ultrasound imaging of tissues Circuital modeling of microfabricated acoustic transducers FEM modeling of microfabricated acoustic transducers: electro-mechano-acoustic coupling MEMS devices for Terahertz imaging of tissues FEM modeling of microbolometers: thermo-opto-mechanical coupling
Learning goals	Understanding the basics of MEMS devices. Capabilities to develop multiphysical models of MEMS devices. Assessing the relevant figures of merit of MEMS for imaging applications.
Teaching methods	Understanding the basics of MEMS devices. Capabilities to develop multiphysical models of MEMS devices. Assessing the relevant figures of merit of MEMS for imaging applications.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on a written questionnaire.
Suggested readings	- Brenner, K.; Ergun, A.S.; Firouzi, K.; Rasmussen, M.F.; Stedman, Q.; Khuri–Yakub, B. Advances in Capacitive Micromachined Ultrasonic Transducers. Micromachines 2019, 10, 152. https://doi.org/10.3390/mi10020152 - A. Lohfink and P. C. Eccardt, "Linear and nonlinear equivalent circuit modeling of CMUTs," in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 52, no. 12, pp. 2163-2172, Dec. 2005. https://doi.org/10.1109/TUFFC.2005.1563260 - G. G. Yaralioglu, S. A. Ergun and B. T. Khuri-Yakub, "Finite-element analysis of capacitive micromachined ultrasonic transducers," in IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 52, no. 12, pp. 2185-2198, Dec. 2005. https://doi.org/10.1109/TUFFC.2005.1563262 - Xiang Yang, Xiang Zhao, Ke Yang, Yueping Liu, Yu Liu, Weiling Fu, Yang Luo, Biomedical Applications of Terahertz Spectroscopy and Imaging, Trends in Biotechnology, Volume 34, Issue 10, 2016, Pages 810-824, ISSN 0167-7799. https://doi.org/10.1016/j.tibtech.2016.04.008 - Vicarelli, L.; Tredicucci, A.; Pitanti, A. Micromechanical Bolometers for Subterahertz Detection at Room Temperature, ACS Photonics 2022, 9, 2, 360–367. https://doi.org/10.1021/acsphotonics.1c01273
Additional information	

Course unit English denomination	**Coupled electrical-thermal-structural Finite Element Analyses**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	2 year June
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Course overview and introduction. General aspects of Finite Element analyses related to the structural, thermal and electrical fields. Structural analyses with plane and solid elements. Thermal analyses with plane and solid elements, implementing thermal conduction, thermal convection and thermal radiation. Coupled field thermal-structural analyses. Coupled field electrical-thermal analyses. Coupled field electrical-thermal-structural analyses. Presentation of a complex test case implementing all the aforementioned physical fields with a specific focus on complex geometry import.
Learning goals	The course is aimed at providing the fundamental know-how for the performance of Multiphysics Finite Element analyses related to the structural, thermal and electrical fields. ANSYS® will be the adopted engineering simulation software.
Teaching methods	The course is aimed at providing the fundamental know-how for the performance of Multiphysics Finite Element analyses related to the structural, thermal and electrical fields. ANSYS® will be the adopted engineering simulation software.

Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on a case study developed during and after the lectures.
Suggested readings	- M. Manzolaro, G. Meneghetti, A. Andrighetto, Thermal–electric numerical simulation of a surface ion source for the production of radioactive ion beams, Nucl. Instrum. Methods Phys. Res., Sect. A 623 (2010) 1061–1069. - G. Meneghetti, M. Manzolaro, A. Andrighetto, Thermal–electric numerical simulation of a target for the production of radioactive ion beams, Finite Elem. Anal. Des. 47 (2011) 559–570. - M. Manzolaro, G. Meneghetti, INTRODUCTION TO THE THERMAL ANALYSIS WITH ANSYS® NUMERICAL CODE, edizioni LIBRERIA PROGETTO, 2014, Padova, ITALY. - G. Meneghetti, M. Manzolaro, M. Quaresimin, INTRODUCTION TO THE STRUCTURAL ANALYSIS WITH ANSYS® NUMERICAL CODE, edizioni LIBRERIA PROGETTO, 2014, Padova, ITALY.
Additional information	

UNIVERSITÀ DEGLI STUDI DI PADOVA

INDUSTRIAL ENGINEERING

Course unit English denomination	**Design and analysis of axial-flow industrial fans**
SS	
Teacher in charge (if defined)	
Teaching Hours	25
Number of ECTS credits allocated	5
Course period	1-2-3 year September (2nd half)
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☐ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Fundamentals of axial-flow industrial fans: applications of industrial axial-flow fans; axial-flow fan operating principle; aerodynamic performance parameters; fan internal flow approximations (from 1D to 3D); radial equilibrium model and blade aerodynamic loading. axial-flow fan aerofoil sections; cascade versus isolated aerofoil aerodynamics. Preliminary design: similarity principles applied to axial-flow fans; selection of the fan configuration best suited to a specific performance requirement; definition of the size and rotational speed of the rotor; definition of the meridional geometry; definition of the velocity diagrams corresponding to the selected blade loading distribution. Aerodynamic design of axial-fan bladings: aerofoil performance charts; definition of the blade geometry; stall margin; effects of the Reynolds number; secondary flows and tip clearance effects. Computational fluid-dynamics applied to axial-flow fan analysis: computational domains best suited to support the different phases of fan design; physical models, numerical schemes and solution algorithms; use of CFD tools for fan aerodynamics (pre-processing tasks, running the simulation, post-processing the results). Experimental fluid dynamics applied to axial-flow fan analysis: basics of fan testing; standard test rig installation types; experimental assessment of the global aerodynamic performance of an axial-flow fan; local flow field measurement techniques suited to support the fan design.

Learning goals	Understanding the major scientific and engineering issues related to axial-flow fan design and analysis (experimental and numerical). Acquiring competence in the fulfilment of the main tasks associated with the aerodynamic design workflow of an axial-flow fan. Ability to implement a CFD analysis to assess a fan design. Ability to design an experimental campaign to assess the global aerodynamic performance of an axial-flow fan.
Teaching methods	Understanding the major scientific and engineering issues related to axial-flow fan design and analysis (experimental and numerical). Acquiring competence in the fulfilment of the main tasks associated with the aerodynamic design workflow of an axial-flow fan. Ability to implement a CFD analysis to assess a fan design. Ability to design an experimental campaign to assess the global aerodynamic performance of an axial-flow fan.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on discussion of the written report on the aerodynamic design and CFD analysis of an axial-fan able to fulfil the performance requirements assigned to each student during the course lessons.
Suggested readings	- Bleier P. F., 1988, Fan handbook - Selection, application and design. McGrawHill, New York. - Masi, M., Fontana, F., Lazzaretto, A., 2017, “On the choice of suitable parameters for the assessment of industrial fans performance and efficiency.” Proceeding of the ASME TurboExpo 2017. GT2017-64032. Charlotte-NC, USA, June 26-30. - Lewis, R. I., 1996, Turbomachinery performance analysis, Arnold, London. - Masi, M., Danieli, P., Lazzaretto, A., 2021, “Overview of the best 2020 axial-flow fan data and inclusion in similarity charts for the search of the best design” J. Turbomach. Paper No: TURBO-21-1157. - Eck, B., 1973, Fans, Pergamon Press. Oxford, UK. - Versteeg H. K., Malalasekera W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method. Pearson Education, 2007. - Masi M., Lazzaretto A., “CFD models for the analysis of rotor-only industrial axial-flow fans”. Proc. International conference on fan noise, technology and numerical methods - FAN 2012, Senlis, France, April 18-20.

- ISO – International Organization for Standard - Technical Committee ISO/TC 117, Fans. “Industrial fans - Performance testing using standardized airways”. ISO 5801:2007, CP 401 - 1214 Vernier, Geneva, Switzerland. 2007.

Additional information

Course unit English denomination	**Eco-informed Materials Choice**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	1-2-3 year July (3rd week)
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to materials selection. Definition of fundamental combinations of materials properties usable as ‘performance indices’ (e.g. prediction of lightness of components according to combinations of density with mechanical properties). Rapid materials selection by representation of indices in material property charts. Extension to environmental studies, by definition of environmental performance indices, with case studies. Presentation of case studies involving thermal properties. The materials life cycle. Ecological data: values, sources, precision. Eco-audits and eco-audit tools (introduction to specific software), with case studies.
Learning goals	The course aims at providing strategies for eco-informed materials selection, i.e. selection of materials combining optimized functionality (mainly but not only structural) and minimized environmental impact. It also aims at clarifying the multiple aspects of materials life cycle, especially concerning recycling procedures, in order to realize real energy and emission savings.
Teaching methods	The course aims at providing strategies for eco-informed materials selection, i.e. selection of materials combining optimized functionality (mainly but not only structural) and minimized environmental impact. It also aims at clarifying the multiple aspects of materials life cycle, especially concerning recycling procedures, in order to realize real energy and emission savings.

Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on home assignment (comprising a quiz questionnaire and a short project)
Suggested readings	- Course slides, provided by the lecturer - M.F. Ashby, Materials and the Environment, Butterworth Heinemann, Oxford, UK (excerpts, provided by the lecturer) - M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, Oxford, UK (excerpts, provided by the lecturer)
Additional information	

Course unit English denomination	**Ecotoxicology as an heuristic approach to environmental engineering**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2-3 year Second semester
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction, Regulations Classification methodologies (REACH, CLP) Toxic Chemicals in general Chemical properties , Classification of chemicals Partition coefficient and degradation parameters Ecotoxicological parameters Ecological risk assessment Chemical properties estimation QSAR approach An introduc0tion to fugacity models
Learning goals	To organize knowledge, based on explanatory principles, about chemicals in the biosphere and their effects. To develop and apply methods and decision tools (ecotox models, LCI, Risk analysis, etc.) to acquire a better understanding of chemical fate and effects in the biosphere. To use biomonitoring: use of organisms to monitor contaminations and to imply possible effects to biota or sources of toxicants to humans; To be critical in environmental decisions. To use your ecotoxicology-knowledge in different fields (work safety, health aspects in confined spaces, etc.)
Teaching methods	To organize knowledge, based on explanatory principles, about chemicals in the biosphere and their effects. To develop and apply methods and decision tools (ecotox models, LCI, Risk analysis, etc.) to acquire a better understanding of chemical fate and effects in the biosphere.

	To use biomonitoring: use of organisms to monitor contaminations and to imply possible effects to biota or sources of toxicants to humans; To be critical in environmental decisions. To use your ecotoxicology-knowledge in different fields (work safety, health aspects in confined spaces, etc.)
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on the discussion of a case study related to the individual PhD project
Suggested readings	- L. Palmeri, A. Barausse and S.E. Jorgensen, Ecological Processes Handbook, CRC Press, 2013 - S.E. Jorgensen and G. Bendoricchio, Fundamentals of Ecological Modelling, third edition, Elsevier, 2001. - Newman MC, MA Unger. 2002. Fundamentals of ecotoxicology, 2nd Edition. CRC/Lewis Press, Boca Raton, FL.
Additional information	

Course unit English denomination	**Electromagnetic fields and biological tissues**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2-3 year April - May
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to electromagnetic field coupled with the human body. Brief introduction on cell membrane and cell biology and electrical properties of tissues as a function of the frequency. Measurements of biological tissue electrical properties. Electric field distribution in inhomogeneous tissues. Mechanism of electric stimulation. Muscle contraction. Tissue heating. Induced current and induced electric field. Mechanisms involved in the interaction of cells/tissues with electric and magnetic field. The electric model of the cell. Coupling the tissue with electric and magnetic fields. Medical uses of electromagnetic fields (e.g. electrochemotherapy, ECT, and magneto fluid Hyperthermia, MFH).
Learning goals	Understanding the electric properties of biological tissues. How the electromagnetic field can be used in medical practice.
Teaching methods	Understanding the electric properties of biological tissues. How the electromagnetic field can be used in medical practice.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on multiple choice questionnaire
Suggested readings	- C. L. Dennis e R. Ivkov, «Physics of heat generation using magnetic nanoparticles for hyperthermia», Int. J. Hyperthermia, vol. 29, n. 8, pagg. 715–729, 2013. - B. Hildebrandt et al., «The cellular and molecular basis of hyperthermia», Crit. Rev. Oncol. Hematol., vol. 43, n. 1, pagg. 33–56, 2002. - G. F. Goya, L. Asín, e M. R. Ibarra, «Cell death induced by AC magnetic fields and magnetic nanoparticles: Current state and perspectives», Int. J. Hyperthermia, vol. 29, n. 8, pagg. 810–818, 2013. - L. M. Mir et al., «Effective treatment of cutaneous and subcutaneous malignant tumours by electrochemotherapy», Br. J. Cancer, vol. 77, n. 12, pagg. 2336–2342, giu. 1998. - L. M. Mir e S. Orlowski, «Mechanisms of electrochemotherapy», Enhanc. Drug Deliv. Using High-Volt. Pulses, vol. 35, n. 1, pagg. 107–118, gen. 1999, doi: 10.1016/S0169-409X(98)00066-0. - J. Gehl, «Electroporation: theory and methods, perspectives for drug delivery, gene therapy and research», Acta Physiol. Scand., vol. 177, n. 4, pagg. 437–447, apr. 2003, doi: 10.1046/j.1365-201X.2003.01093.x. - M. Marty et al., «Electrochemotherapy – An easy, highly effective and safe treatment of cutaneous and subcutaneous metastases: Results of ESOPE (European Standard Operating Procedures of Electrochemotherapy) study», Eur. J. Cancer Suppl., vol. 4, n. 11, pagg. 3–13, nov. 2006, doi: 10.1016/j.ejcsup.2006.08.002.
Additional information	

Course unit English denomination	**Entrepreneurship and Startup**
SS	
Teacher in charge (if defined)	
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	1-2-3 year January - February
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	- Entrepreneurship - The team and The early decisions - From The idea to The market - Intellectual Property Rights - Business Models - The financials of a startup - Funding a startup
Learning goals	The course is aimed at those who have undertaken or are undertaking research paths which can result in potential entrepreneurial ventures. The aim of this course is to provide participants with the main elements needed to establish an innovative start-up. Each participant develops and understanding of their propensity to be an entrepreneur, followed by awareness of how ready they are to set up an entrepreneurial project. The course aims to expand participants' ability to embark on an entrepreneurial journey by providing them with greater confidence and competence. By the end of the programme, participants will perceive their entrepreneurial ability to have greatly improved. Main learning goals: - understanding the characteristics of a technology and innovation-based start-up; - using feasibility criteria applied to a business idea;

	- understanding the main features of a founding team and the major problems associated with it; - defining and evaluate a product and/or service concept; understanding and appling intellectual property protection and related processes; - evaluating the market aspects of a business idea; - designing and evaluate business models to be applied to a business idea; - understanding and draw up the economic and financial aspects of a start-up; - assessing cash flow aspects; - evaluating different options for financing a start-up; - understanding what professional investors are interested in and how they assess it.
Teaching methods	The course is aimed at those who have undertaken or are undertaking research paths which can result in potential entrepreneurial ventures. The aim of this course is to provide participants with the main elements needed to establish an innovative start-up. Each participant develops and understanding of their propensity to be an entrepreneur, followed by awareness of how ready they are to set up an entrepreneurial project. The course aims to expand participants' ability to embark on an entrepreneurial journey by providing them with greater confidence and competence. By the end of the programme, participants will perceive their entrepreneurial ability to have greatly improved. Main learning goals: - understanding the characteristics of a technology and innovation-based start-up; - using feasibility criteria applied to a business idea; - understanding the main features of a founding team and the major problems associated with it; - defining and evaluate a product and/or service concept; understanding and appling intellectual property protection and related processes; - evaluating the market aspects of a business idea; - designing and evaluate business models to be applied to a business idea; - understanding and draw up the economic and financial aspects of a start-up; - assessing cash flow aspects; - evaluating different options for financing a start-up; - understanding what professional investors are interested in and how they assess it.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on the discussion of a case study of a technology-based startup
Suggested readings	- Thomas R. Ittelson (2009), Financial Statements: A Step-by-Step Guide to Understanding and Creating Financial Reports, Career Press. - Ferrati, F. & Muffatto, M. (2021). "Reviewing Equity Investors' Funding Criteria: A Comprehensive Classification and Research Agenda". Venture Capital, Vol. 23: No. 2, pp. 1-22. - Noam Wasserman (2013) The Founder's Dilemmas: Anticipating and Avoiding the Pitfalls That Can Sink a Startup, Princeton University Press.
Additional information	

Course unit English denomination	**Experimental measurements in thermal fluid dynamics**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	1-2 year February
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to the expression of uncertainty in measurements: theory and practical examples. Measurements of pressure, temperature (thermocouples, infrared thermography, resistance temperature detectors) and flow rate. Introduction to the determination of the heat transfer coefficient during two-phase flow (condensation, flow boiling) inside channels. Liquid film thickness measurements inside channels by means of optical techniques (shadowgraphy, chromatic confocal imaging, interferometry). Heat transfer measurements during dropwise condensation. Measurements of solar radiation and concentrated solar flux. Experimental calibration of a thermocouple. Experimental measurement of temperature and mass flow rate during two-phase flow.
Learning goals	At the end of the course, the PhD students will learn: - how to perform an uncertainty analysis starting from experimental data, - how to build a thermocouple and how to perform a calibration, - the operating principle of temperature, pressure and flow meter sensors, as well as the measuring techniques for solar radiation and concentrated solar flux, - how to perform thermal and optical measurements during two-phase heat transfer.

Teaching methods	At the end of the course, the PhD students will learn: - how to perform an uncertainty analysis starting from experimental data, - how to build a thermocouple and how to perform a calibration, - the operating principle of temperature, pressure and flow meter sensors, as well as the measuring techniques for solar radiation and concentrated solar flux, - how to perform thermal and optical measurements during two-phase heat transfer.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on a home assignment
Suggested readings	- GUM: Guide to the Expression of Uncertainty in Measurement. http://www.bipm.org/en/publications/guides/gum.html - Termodinamica applicata, A. Cavallini, L. Mattarolo, CLEUP Editore, cap. XIII. - V.J. Nicholas, D.R. White. 1994. Traceable Temperatures – An Introduction to Temperature Measurement and Calibration, John Wiley & Sons Ltd, West Sussex, England. - Bortolin S., Tancon M., Del Col D., Heat transfer enhancement during dropwise condensation over wettability-controlled surfaces, in: M. Marengo and J. De Coninck (Eds.), The Surface Wettability Effect on Phase Change, Springer, Cham, 2022, DOI: https://doi.org/10.1007/978-3-030-82992-6_3 - Del Col D., Bortolin S., Azzolin M., Measuring Heat Transfer Coefficient During Condensation Inside Channels, in: J. Meyer and M. de Paepe (Eds.), The art of measuring in thermal sciences, CRC Press (Taylor and Francis Group), Boca Raton, 2021, DOI: https://doi.org/10.1201/9780429201622
Additional information	

UNIVERSITÀ DEGLI STUDI DI PADOVA

INDUSTRIAL ENGINEERING

Course unit English denomination	**Finite Element Method (FEM)**
SS	
Teacher in charge (if defined)	
Teaching Hours	30
Number of ECTS credits allocated	6
Course period	1 year Fall 2024
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Missing
Learning goals	Finite Element Method in Engineering: Theory and Practice
Teaching methods	
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on oral examination
Suggested readings	- Handouts from the lectures.

	- Giuseppe Gambolati e Massimiliano Ferronato "Lezioni di Metodi Numerici per l'Ingegneria, Progetto, 568 pp, 2022. - Thomas J.R. Huges, The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, Prentice-Hall, 833 pp, 1987. - Myron B. Allen et al., Numerical Modeling in Science and Engineering, J. Wiley, 412 pp, 1988.
Additional information	The course will be activated with a minimum of 5 students.

Course unit English denomination	**From the Energy Simulation of Buildings to the Environmental Certification Protocols**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	1-2-3 year June - July
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Energy in buildings (thermal and energy properties of building envelopes, boundary conditions for the design and the energy analysis, detailed analysis of components and devices, …), Energy Certification in Italy, Environmental and Sustainability Protocols (GBC, Itaca, BREEAM…), use of tools for the Energy Simulations of buildings and plants.
Learning goals	- Analysis of energy problems linked to the building sector. - Understand and address the energy dynamics of the building and each part of it. - Known of procedures, objectives and differences between the energy certification and global environmental and sustainability protocols. - Global impact on the CO_2 footprint generated by buildings. - Advantages connected to the following fields of study following the application of environmental protocols: Ecology, Energy and Water Use, Indoor environment (health and well-being), Management processes, Materials, Pollution, Transport and Waste - Use of detailed simulation tools normally used in the energy analysis of the building field. - Analysis of the energy saving potential by using dynamic simulations in the energy audit field. Impact N18
Teaching methods	- Analysis of energy problems linked to the building sector.

	- Understand and address the energy dynamics of the building and each part of it. - Known of procedures, objectives and differences between the energy certification and global environmental and sustainability protocols. - Global impact on the CO_2 footprint generated by buildings. - Advantages connected to the following fields of study following the application of environmental protocols: Ecology, Energy and Water Use, Indoor environment (health and well-being), Management processes, Materials, Pollution, Transport and Waste - Use of detailed simulation tools normally used in the energy analysis of the building field. - Analysis of the energy saving potential by using dynamic simulations in the energy audit field. Impact N18
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on written questionnaire and/or oral discussion
Suggested readings	- Ashrae Standard 90.1-2022—Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings - Fatma S. Hafez et al. (2023) Energy Efficiency in Sustainable Buildings: A Systematic Review with Taxonomy, Challenges, Motivations, Methodological Aspects, Recommendations, and Pathways for Future Research. Energy Strategy Reviews Volume 45, January 2023, 101013 - Zhihang Zheng et al. (2024) Review of the building energy performance gap from simulation and building lifecycle perspectives: Magnitude, causes and solutions. Developments in the Built Environment Volume 17, March 2024, 100345.
Additional information	

Course unit English denomination	**Geometric Modeling of Anatomical Parts and Medical Devices**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	1-2-3 year June
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Within the framework of the so-called personalized medicine, the course aims to provide the student, through conventional lectures and practical demonstrations, an overview on geometric modeling techniques for digital and physical fabrication of anatomical parts and for the realization of personalized medical devices. Topics: General aspects of Reverse Engineering, External/Internal anatomic parts acquisition methods, Free form/Surface modeling design of anatomical replicas, CAD modeling design of medical devices, Clinical cases description.
Learning goals	PhD Students will have the opportunity to see these examples and take familiarity and ability to work with reconstructed 3D models and CAD modeling. These outcomes will be demonstrated through an assignment that will be discussed at the end of the course.
Teaching methods	PhD Students will have the opportunity to see these examples and take familiarity and ability to work with reconstructed 3D models and CAD modeling. These outcomes will be demonstrated through an assignment that will be discussed at the end of the course.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on a clinical case study developed during the lectures
Suggested readings	- Mussi, E., Furferi, R., Volpe, Y., Facchini, F., McGreevy, K. S., & Uccheddu, F. (2019). Ear reconstruction simulation: from handcrafting to 3D printing. Bioengineering, 6(1), 14. - Buonamici, F., Furferi, R., Governi, L., Lazzeri, S., McGreevy, K. S., Servi, M., ... & Volpe, Y. (2020). A practical methodology for computer-aided design of custom 3D printable casts for wrist fractures. The Visual Computer, 36(2), 375-390. - Mussi, E., Mussa, F., Santarelli, C., Scagnet, M., Uccheddu, F., Furferi, R., ... & Genitori, L. (2020). Current practice in preoperative virtual and physical simulation in neurosurgery. Bioengineering, 7(1), 7. - Volpe, Y., Furferi, R., Governi, L., Uccheddu, F., Carfagni, M., Mussa, F., ... & Genitori, L. (2018). - Surgery of complex craniofacial defects: A single-step AM-based methodology. Computer Methods and Programs in Biomedicine, 165, 225-233. - Uccheddu, F., Ghionzoli, M., Volpe, Y., Servi, M., Furferi, R., Governi, L., ... & Messineo, A. (2018). A novel objective approach to the external measurement of pectus excavatum severity by means of an optical device. The Annals of thoracic surgery, 106(1), 221-227
Additional information	

Course unit English denomination	**Green Chemistry and Technology**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2 year June - July
Course delivery method	☐ In presence ☒ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to Green Chemistry and Green Technology; The principles of sustainable and Green Chemistry and Engineering: Chemistry and the environment; Green chemistry and sustainable development; Introduction to Life Cycle Assessment (LCA) of products; Green Nanotechnology: nanomaterials from green sources and green processes; Green approaches for energy and fuel cells; Green metrics: evaluating the "Greenness" of chemical processes and products (with laboratory).
Learning goals	To understand the basic principles of green chemistry and green engineering and to acquire the ability to perform a preliminary assessment of a material and process greenness.
Teaching methods	To understand the basic principles of green chemistry and green engineering and to acquire the ability to perform a preliminary assessment of a material and process greenness.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	None
Examination methods (if applicable)	Students will be asked to write an essay on a specific aspect or process among those treated. The essay (in English) will be submitted and discussed on a date to be agreed by the end of September
Suggested readings	- Anastas, P. T.; Warner, J. C.; Green Chemistry: Theory and Practice; Oxford University Press: New York, 2000 (available at Biblioteca Centrale di Ingegneria) - Lancaster, M.; Green Chemistry: an introductory text; Royal Society of Chemistry: Cambridge, 2010 (available at Biblioteca Centrale di Ingegneria) - Jiménez-González, C.C.; Constable, D.; Green chemistry and engineering: a practical design approach; Wiley: Hoboken, New Jersey, 2011 (available online at https://galileodiscovery.unipd.it) - Benvenuto, Mark A., editor.; Ruger, George, editor; Green chemistry and technology; 2021; Berlin; Boston: De Gruyter (available online at https://galileodiscovery.unipd.it) - McKeag, Thomas, Green chemistry in practice: greener material and chemical innovation through collaboration, 2023; Kidlington, England; Cambridge, MA: Elsevier (available online at https://galileodiscovery.unipd.it) - Tiwari, Vinod K., Tiwari, Vinod K., Green chemistry: introduction, application and scope, 2022; 1st ed. 2022; Singapore: Springer (available online at https://galileodiscovery.unipd.it) - The lectures' slides will be made available to all the participants.
Additional information	The last lesson will be a workshop on the application of green metrics.

Course unit English denomination	**Introduction to Model Order Reduction**
SS	
Teacher in charge (if defined)	
Teaching Hours	5
Number of ECTS credits allocated	1
Course period	2-3 year May
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Model order reduction (MOR) is a technique for reducing the computational complexity of mathematical models in numerical simulations. As such it is closely related to the concept of metamodeling, with applications in all areas of mathematical modelling. In this short course, the main numerical approaches to perform MOR will be presented. In particular, the Proper Orthogonal Decomposition (POD) will be discussed, and a basic implementation of the algorithm will be presented. This basic POD algorithm will be then applied to speed up time domain simulations of a thermal problem in MATLAB.
Learning goals	Knowledge of the main techniques for Model Order Reduction applied to dynamics models
Teaching methods	Knowledge of the main techniques for Model Order Reduction applied to dynamics models
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on the code implemented during the course
Suggested readings	- Benner P., Grivet-Talocia S., Quarteroni A., Rozza G., Schilders W., Magdeburg L. M. S. Model Order Reduction. Three volumes. Doi: 10.1515/9783110499001 - Benner, P., Feng, L. (2014). A Robust Algorithm for Parametric Model Order Reduction Based on Im- plicit Moment Matching. In: Quarteroni, A., Rozza, G. (eds) Reduced Order Methods for Modeling and Computational Reduction. MS&A - Modeling, Simulation and Applications, vol 9. Springer, Cham. https://doi.org/10.1007/978-3-319-02090-7_6 - Feng, L., Yue, Y., Banagaaya, N. et al. Parametric modeling and model order reduction for (electro-)thermal analysis of nanoelectronic structures. J.Math.Industry 6, 10 (2016). - Y. Liang, H. Lee, S. Lim, W. Lin, K. Lee, and C. Wu. Proper orthogonal decomposition and its applica- tions—part i: Theory. Journal of Sound and Vibration, vol. 252, no. 3, pp. 527–544, 2002 - S. Brunton, J. Nathan Kutz, Data-Driven Science and Engineering. Doi: https://doi.org/10.1017/9781108380690
Additional information	

Course unit English denomination	**Introduction to Numerical Methods in Gas Dynamics for Fluid Machinery**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2-3 year February
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	This course focuses on the principles and applications of unsteady gas dynamics in the context of turbomachinery, exploring the behavior of compressible flow under high-speed conditions prevalent in modern gas turbines and compressors. The focus is related to unsteady flow phenomena and their numerical modeling aspect which are fundamental for understanding turbomachinery performance and optimization. Thus, the course covers the fundamental concepts related to the theory of hyperbolic systems of equations, focusing on non-stationary phenomena in compressible flows. It begins with an introduction to the hyperbolic system of equations, specifically the Euler equations of gas dynamics. The theory of characteristics is then presented, with a discussion on its applications to conservative systems. The course also introduces Riemann problems, including jump relations and the dynamics of shock waves and expansion fans. Practical application is explored through a time-dependent gas dynamics problem in the turbomachinery field. Additionally, the course provides basic knowledge of compiled programming languages, emphasizing modern Fortran90 for high-performance computing and applications to compressible flows in turbomachinery.
Learning goals	The main learning goals of the course are to understand and apply the principles of unsteady gas dynamics and hyperbolic systems of equations within the context of fluid flows in turbomachinery, gain insights into numerical

	modeling of complex flow phenomena, and develop skills in high-performance computing using modern Fortran90.
Teaching methods	The main learning goals of the course are to understand and apply the principles of unsteady gas dynamics and hyperbolic systems of equations within the context of fluid flows in turbomachinery, gain insights into numerical modeling of complex flow phenomena, and develop skills in high-performance computing using modern Fortran90.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation is based on an oral discussion
Suggested readings	- De Vanna, F., et al. (2020). A sharp-interface immersed boundary method for moving objects in compressible viscous flows. Computers and Fluids, 201, 104415. - De Vanna, F., et al. (2021). Unified wall-resolved and wall-modeled method for large-eddy simulations of compressible wall-bounded flows. Physical Review Fluids, 6(3), 034614. - De Vanna F., et al. (2023). Effect of convective schemes in wall-resolved and wall-modeled LES of compressible wall turbulence, Computers and Fluids - De Vanna, F., et al. (2023). URANOS: A GPU accelerated Navier-Stokes solver for compressible wall-bounded flows. Computer Physics Communications, 287, 108717.
Additional information	

Course unit English denomination	**Particle Image Velocimetry: theory and applications**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	1-3 year December – January
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	PIV is an optical, mild intrusive measuring technique largely applied in many engineering fields to study and optimize fluid dynamic problems. Once a highly expensive tool, in the last years it has become a more accessible and diffuse technology in research facilities and industries thanks to the reduction of the costs of digital sensors (SCMOS) and laser sources. The course will focus on the theoretical and practical aspects of the Particle Image Velocimetry including the theoretical background (such as geometrical and physical optics), the component selection criteria to optimize an experiment set-up and the post processing algorithms. Application examples to real cases will be discussed, highlighting the actual peculiarities of setting up a PIV experiment for a given problem. While the course will mainly focus on basics Set-Up as the 2D Mono and Stereo PIV, advanced techniques such as the Dual Pane, the Tomo-PIV and particle tracing techniques will be also introduced at the end of the course. The course will end with and experimental activity that will involve the students in the main steps of a PIV experimental champaign such as: the cameras set-up, the calibration procedure, the acquisition and the application of pre and post-processing filter to the recordings.
Learning goals	The main learning objectives of the course are the following: • Understand the basic principles of PIV and its multidisciplinary nature; • Acquire the methodology to critically discuss a PIV experiment;

	• Acquire the methodology to design and set up a PIV experiment, selecting proper equipment and techniques.
Teaching methods	The main learning objectives of the course are the following: • Understand the basic principles of PIV and its multidisciplinary nature; • Acquire the methodology to critically discuss a PIV experiment; • Acquire the methodology to design and set up a PIV experiment, selecting proper equipment and techniques.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Students will be asked to identify a PIV application and write an essay describing the experimental setup, expected results, and potential challenges.
Suggested readings	Particle Image Velocimetry – a practical guide. M Raffel, C. Willert, S. Wereley and J. Kompenhans. ISBN 978-3-540-72307-3 Second Edition Springer Berlin Heidelberg New York.
Additional information	The course lesson will be held at the ITC - CNR thermo-fluid dynamic laboratory at the “Area territoriale di Ricerca di Padova” – Corso Stati Uniti,4 - 35127 Padova – Italy

Course unit English denomination	**Powder flowability**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2-3 year June-July
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	The course provides fundamental knowledge, theory and practical information for researchers addressing challenges related to powder flowability. PART 1: Key properties and characterization of particulate materials (particle shape, size, apparent density, surface area, porosity). Types of particle interactions (solid-solid contact) and the definition of cohesion. Definition and measurement of powder flowability. PART 2: Static and dynamic stress analysis in solids (solid mechanics). Yield criteria for powders (Mohr-Coulomb analysis). Active and passive stress states. Criteria for the design of storage units to ensure flow (Jenike approach).
Learning goals	The main learning goals are: - Understanding powder flowability - Measuring and interpreting flowability data - Understanding the implications of flowability in practical cases
Teaching methods	The main learning goals are: - Understanding powder flowability - Measuring and interpreting flowability data - Understanding the implications of flowability in practical cases

Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on a written questionnaire
Suggested readings	- Nedderman, R. M. (1992). Statics and Kinematics of Granular Materials. Cambridge University Press. - Holdich, Richard G. (2002). Fundamentals of Particle Technology. Shepshed: Leicestershire, Midland Information Technology & Publishing. - Schulze, D. (2008). Powders and Bulk Solids: Behavior, Characterization, Storage. Springer. -Barletta, D., Poletto, M., & Santomaso, A. C. (2019). Bulk Powder Flow Characterisation Techniques. In A. Hassanpour, C. Hare, & M. Pasha (Eds.), Powder Flow: Theory, Characterisation and Application (pp. 64–146). Royal Society of Chemistry.
Additional information	The course finishes with a practical session in the laboratory.

Course unit English denomination	**Principles and Applications of Life Cycle Assessment of Energy Systems**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1-2-3 year September
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	During the Ph.D. course lessons, the four stages of the LCA will be presented following the specifications stated on the standards ISO 14040 and 14044: - Goal and scope. - Inventory analysis. - Impact assessment. - Interpretation. The most used and complete models and methods for the impact assessment and updated databases for the Inventory analysis will be presented. The use of LCA for the environmental labels system will be analyzed. The course focuses on the assessment of energy systems and the energetic aspects; for this reason, the proper evaluation of the reference system for the electricity and heat production will be deepened. Several examples of LCA will be presented with the aim of understanding the importance of: - The functional unit. - The system boundaries. - Any assumptions and limitations. - Data quality requirements. - The allocation methods. - The impact categories.

	Finally, the code SimaPro, a professional tool to collect, analyze and monitor the sustainability performance data of products, services, etc., will be presented and used to conduct a Life Cycle Analysis of a Renewable Plant.
Learning goals	The main learning goals of the course are the following:. - Understanding the basic knowledge of LCA. - Understandingm the basic principles of tools that allow the conduction of an LCA. - acquiring advanced capacities to perform a basic LCA analysis.
Teaching methods	The main learning goals of the course are the following:. - Understanding the basic knowledge of LCA. - Understandingm the basic principles of tools that allow the conduction of an LCA. - acquiring advanced capacities to perform a basic LCA analysis.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	None
Examination methods (if applicable)	The final evaluation will be based on a report that describes how a basic LCA analysis performed in SimaPro has been performed
Suggested readings	- Stoppato A., Benato A., De Vanna F. (2021), "Environmental impact of energy systems integrated with electrochemical accumulators and powered by renewable energy sources in a life-cycle perspective", Applied Sciences, Volume 11, Issue 62. - Stoppato A. and Benato A. (2020), "Life cycle assessment of a commercially available organic Rankine cycle unit coupled with a biomass boiler", Energies 13(7),1835. - Cavallin Toscani A., Stoppato A., Benato A. (2019), "LCA of a concert: Evaluation of the Carbon footprint and of Cumulative energy demand", ECOS 2019 - Proceedings of the 32nd International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems pp. 3203-3213. - Fantinato, D., Stoppato A., Benato A. (2019), "LCA analysis of a low-energy residential building", ECOS 2019 - Proceedings of the 32nd International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems pp. 3153-3165. - Stougie, L., Giustozzi, N., van der Kooi, H., Stoppato, A. (2018), "Environmental, economic and exergetic sustainability assessment of power

generation from fossil and renewable energy sources", International Journal of Energy Research 42(9), pp. 2916-2926.
- Stoppato A. (2008), "Life cycle assessment of photovoltaic electricity generation", Energy 33(2), pp. 224-232.

Additional information

Course unit English denomination	**Python for numerical heat transfer modeling and building physics**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	1-2 year March - April
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Despite the great rise of data-driven methods, physics-based modeling still represents a crucial tool for engineering Ph.D. students and researchers, as it represents a flexible and adaptable tool. This course aims to give an introduction and a practical guideline to transient heat transfer and building physics modeling through Python programming language. After a brief guide to the language and its features, lectures will focus on implementing real case scenarios like modeling heat transfer through a surface, modeling the heat flux in a radiant floor, and simulating the whole building's transient behavior. General outline: - Brief introduction to Python: data structures, basic loops, most used libraries, plots. - First models: modeling heat transfer through a 1D element, radiant panel. - More complex models: building RC network, introduction to model calibration. - Final lesson: project discussion.
Learning goals	- Implicit and explicit solution schemes - Basic principles to set and solve physics-based systems - Introduction to Python for scientific applications
Teaching methods	- Implicit and explicit solution schemes - Basic principles to set and solve physics-based systems

	- Introduction to Python for scientific applications
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on the discussion of a case study within the individual PhD project
Suggested readings	Introduction to python - Transition from MATLAB to Python. https://www.enthought.com/wp-content/uploads/2019/08/Enthought-MATLAB-to-Python-White-Paper_.pdf - Think Python. https://greenteapress.com/wp/think-python-2e/ Physics modeling - ASHRAE Fundamentals. Incropera F., De Witt D. Fundamentals of Heat Transfer, John Wiley&Sons. 1981 or other edition. - Building Physics - Applications in Python. https://www.researchgate.net/publication/353514722_Building_Physics_-_Applications_in_Python - Solving inverse problems in building physics: an overview of guidelines for a careful and optimal use of data. https://srouchier.github.io/files/2018-enb-review.pdf
Additional information	

Course unit English denomination	**S: Statistics for Engineers**
SS	
Teacher in charge (if defined)	
Teaching Hours	40
Number of ECTS credits allocated	8
Course period	1-2-3 year 03/02/2025 10/02/2025 27-30/06/2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 90% of the course) ☐ No
Course unit contents	In this course will be developed the following topics: 1) introduction to descriptive statistics; 2) introduction to inferential statistics; 3) introduction to linear and non-linear regression models; 4) introduction to supervised and unsupervised Machine Learning algorithms; 5) Design of Experiments.
Learning goals	The objective of the course is to provide the fundamental statistical concepts required for PhD students in engineering. The course will start with an introduction to descriptive statistics and basic inferential statistics methods, then some more advanced techniques like experimental designs (Design Of Experiments) and Machine Learning algorithms will be presented. Students will be provided the theoretical concepts which are needed to deal with data of different nature, including data from the PhD project they are developing. Students will be introduced to some user-friendly statistical software and they will learn how to carry out a statistical analysis developing their own project.
Teaching methods	The objective of the course is to provide the fundamental statistical concepts required for PhD students in engineering. The course will start with an introduction to descriptive statistics and basic inferential statistics methods, then some more advanced techniques like experimental designs (Design Of Experiments) and Machine Learning algorithms will

	be presented. Students will be provided the theoretical concepts which are needed to deal with data of different nature, including data from the PhD project they are developing. Students will be introduced to some user-friendly statistical software and they will learn how to carry out a statistical analysis developing their own project.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	The final evaluation will be based on the discussion of two projects developed individually or in teams of no more than three people. Students are expected to describe and analyse one or two case studies using the statistical techniques presented during t
Suggested readings	Materials (slides, datasets, etc.) of the course will be provided by the course leaders.
Additional information	The course is structured into 2 online (February) and a Summer School of 4 days (June). The Summer School will take place in Villa San Giuseppe, Monguelfo, Bolzano province. During the course an introduction to the use of the following statistical softwar

Course unit English denomination	**Smart Technologies for the sustainability of the food chain**
SS	
Teacher in charge (if defined)	
Teaching Hours	15
Number of ECTS credits allocated	3
Course period	2 year April - May
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Technologies for the sustainability of the food chain: integration, interaction and optimization of energy flows within and between food chain sectors, energy efficiency and improved preservation conditions. Refrigeration systems and heat pumps working with natural refrigerants. State-of-the art technologies in commercial refrigeration and in transport refrigeration and last mile delivery. Field monitoring, control and management, field data processing. Experience with a CO2 unit for transport refrigeration at thermal-fluid dynamic lab at CNR-ITC.
Learning goals	Acquisition of general knowledge about: Emissions related to the food chain (post farm gate); thermal processes involved in the food chain and their integration; special focus on cold chain; use of heat pumps in place of fuel burners (opportunities and limits); circuits for heat pumps and refrigeration systems working with natural refrigerants.
Teaching methods	Acquisition of general knowledge about: Emissions related to the food chain (post farm gate); thermal processes involved in the food chain and their integration; special focus on cold chain; use of heat pumps in place of fuel burners (opportunities and limits);

	circuits for heat pumps and refrigeration systems working with natural refrigerants.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation based on the analysis and discussion of a case study
Suggested readings	- IEA, HPT Annex 58, 2023 Report no. HPT-AN58-2 High-Temperature Heat Pumps-Task 1 – Technologies-Task Report - Fabris, F, Fabrizio, M., Marinetti, S., Rossetti, A., Minetto, S., 2024. Evaluation of the carbon footprint of HFC and natural refrigerant transport refrigeration units from a life-cycle perspective. International Journal of Refrigeration Volume 159, Pages 17 – 27 March 2024 - F. Fabris, P. Artuso, S. Marinetti, S. Minetto, A. Rossetti, 2021. Dynamic modelling of a CO2 transport refrigeration unit with multiple configurations. Applied Thermal Engineering, Vol. 189 - MultiPACK -H2020 No 723137, 2021 Demonstration of the next generation standardised integrated cooling and heating packages for commercial and public buildings based on environment-friendly carbon dioxide vapour compression cycles- Deliverable D4.7- Technical Report on verified supermarket packs - Selvnes, H., Jenssen, S., Alexis Sevault,A., Widell,K.N., Ahrens, M.U., Ren, S., Hafner, A.2022 Integrated CO2 refrigeration and heat pump systems for dairies. 15th IIR-Gustav Lorentzen conference on Natural Refrigerants | June 13-15 | Trondheim, Norway - ENOUGH- European Food Chain Supply to reduce GHG emissions by 2050- PROJECT NO: 101036588, 2023 Deliverable D1.1 A model for calculating emissions from food
Additional information	

Course unit English denomination	**Stochastic and Gradient Methods for Single- and Multi-Objective Optimization**
SS	
Teacher in charge (if defined)	
Teaching Hours	5
Number of ECTS credits allocated	1
Course period	2-3 year October
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Numerical optimization is a powerful method aimed at improving a given objective function by acting on a set of parameters called design variables. This approach holds significant importance in engineering scenarios to increase the performance of a device by modifying, for example, its geometric parameters corresponding to the design variables. However, when dealing with complex problems featuring numerous parameters and objective functions, relying solely on a “try-and-catch” approach becomes impractical for identifying the optimal configuration. In this short course, the main approaches to perform single- and multi-objective optimizations will be presented. Specifically, stochastic and gradient-based techniques will be discussed, and basic implementations of the algorithms in MATLAB language will be presented.
Learning goals	Knowledge of the main techniques to perform stochastic and gradient-based optimizations
Teaching methods	Knowledge of the main techniques to perform stochastic and gradient-based optimizations
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	The final evaluation will be based on the code implemented during the course
Suggested readings	- Kennedy, J., & Eberhart, R. (1995, November). Particle swarm optimization. In Proceedings of ICNN'95-international conference on neural networks (Vol. 4, pp. 1942-1948). ieee. DOI: 10.1109/ICNN.1995.488968. - Storn, R., & Price, K. (1997), Differential evolution-a simple and efficient heuristic for global optimization over continuous spaces. Journal of global optimization, 11, 341-359. DOI: 10.1023/A:1008202821328. - Deb, K., Pratap, A., Agarwal, S., & Meyarivan, T. A. M. T. (2002). A fast and elitist multiobjective genetic algorithm: NSGA-II. IEEE transactions on evolutionary computation, 2002, 6(2), 182-197. DOI: 10.1109/4235.996017. - Bendsoe, M. P. & Sigmund, O. (2013). Topology optimization: theory, methods, and applications. Springer Science & Business Media. ISBN: 3662050862
Additional information	

Course unit English denomination	**Technological Advancements in Electromobility**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1 year May
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	First lesson deals with the conventional battery chargers for electric vehicles. Second and third lessons deal with the working principles of wireless power transfer systems (WPTSs). Fourth lesson gives a detailed description of the characteristics of a WPTS with series-series compensation. Fifth lesson consists in a demonstration of the functioning of a prototypal WPTS.
Learning goals	Acquire the basic concepts related to the charging of electric vehicle batteries, with particular attention to the wireless technology.
Teaching methods	Acquire the basic concepts related to the charging of electric vehicle batteries, with particular attention to the wireless technology.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	

Examination methods (if applicable)	Final evaluation will be based on oral questions
Suggested readings	-Slides from lectures - Selected papers
Additional information	

Course unit English denomination	**The Role of Energy Storage Technologies and Waste Heat Recovery Units in the Transition to a Future Sustainable Energy System**
SS	
Teacher in charge (if defined)	
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	1-2-3 year February - March
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	To move towards a sustainable power generation system, there is a need to properly use the energy produced by renewable energy plants, as well as to better exploit each source of waste heat. To do that, the point is to have access to energy storage technologies and waste heat recovery units as well as to be able to integrate them into more complex energy systems. The idea is to build up hybrid energy systems in which renewable and fossil-based plants, energy storage systems, and waste heat recovery units work in synergy to supply electricity, heat, cold, water, and fuels (e.g., hydrogen, biogas, biomethane, etc.) in the most effective mode. In this context, the first objective of the COURSE is to present and classify the energy storage technologies and the waste heat recovery units as well as to define the concept and working principle of the hybrid system. After that, attention will be paid to the design of the storage technologies and the waste heat recovery units. In particular, for the storage units, the focus will be on the mechanical and thermal energy storage technologies and will consider the thermodynamic cycles, the up-to-date ways of construction, and the economic aspects. In this way, the technologies will not be analysed only as black-box storage devices, but considering, e.g., the thermodynamic cycles themselves allowing the conversion of electricity into heat during the charging phase and the conversion of heat into electricity during the discharge process. In addition to that and according to the needs of the grid or the renewable plant, different

	reference cycles and configurations will be presented, as well as their control strategies. In a similar way, the waste heat recovery units will be presented taking into account the thermodynamic, the economic, and the technical point of view. After the technology overview, they will be compared on the basis of technical, economic, and environmental indexes. Finally, being storage and waste heat technologies fundamental to boost energy efficiency and spread renewable plants, the benefits of inserting all of them into a unique hybrid system will be presented in conjunction with optimisation techniques able to take into account not only the requested fluxes (electricity, heat, cold, etc.) but also the specific features of each technology. In this manner, the most suitable hybrid system configuration can be designed.
Learning goals	The main learning goals of the course are the following: - understanding the basic knowledge about the functioning of energy markets. - understanding the directives and goals that guide the energy transition. - understanding the working principle, characteristics, and barriers of both energy storage technologies and waste heat recovery units. - identifing technologies for storing and recovering energy. - being capable of selecting the most appropriate technologies for improving the system efficiency, economy, and ecology.
Teaching methods	The main learning goals of the course are the following: - understanding the basic knowledge about the functioning of energy markets. - understanding the directives and goals that guide the energy transition. - understanding the working principle, characteristics, and barriers of both energy storage technologies and waste heat recovery units. - identifing technologies for storing and recovering energy. - being capable of selecting the most appropriate technologies for improving the system efficiency, economy, and ecology.
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	None
Examination methods (if applicable)	The final evaluation will be based on the discussion of a case study proposed during the course

Suggested readings	- Redjeb Y, Kaabeche-Djerafi K., Stoppato A., Benato A. (2021), “The IRC-PD Tool: A Code to Design Steam and Organic Waste Heat Recovery Units”, Energies, 14(18), 5611. - Cavazzini G., Pavesi G., Ardizzon G. (2018), “A novel two-swarm based PSO search strategy for optimal short-term hydro-thermal generation scheduling”, Energy Conversion and Management, 164, 460-481. - Benato A. and Stoppato A. (2018), “Pumped Thermal Electricity Storage: A technology overview”, Thermal Science and Engineering Progress, Vol. 6, pp. 301–315. - Benato A. and Stoppato A. (2018), “Energy and cost analysis of an Air Cycle used as prime mover of a Thermal Electricity Storage”, Journal of Energy Storage, Volume 17, June 2018, Pages 29–46. - Benato A. (2017), “Performance and Cost Evaluation of an Innovative Pumped Thermal Electricity Storage Power System”, Energy, Volume 138, 1 November 2017, Pages 419-436 - Stoppato A. and Benato A. (2017), “The Importance of Energy Storage”. World Scientific Series in Current Energy Issues, Energy Storage - Volume 4, Pages: 1-26, Marcus Enterprise LLC, USA & University of South Carolina, USA. - Pezzuolo A., Benato A., Stoppato A., Mirandola A. (2016), “The ORC-PD: A versatile tool for fluid selection and Organic Rankine Cycle unit design”, Energy, Volume 102, 01 May 2016, Pages 605-620. - Benato A., Stoppato A., Mirandola A. (2016), “Renewable Energy Conversion and Waste Heat Recovery Using Organic Rankine Cycles”, Edited Book “Renewable Energy Systems”. Published by Nova Science Publishers, USA, 1 January 2016. - Destro, N., Benato, A., Stoppato, A., Mirandola, A. (2016), “Components design and daily operation optimization of a hybrid system with energy storages”, Energy, 2016, 117, pp. 569–577. - Cavazzini, G. and Dal Toso, P. (2015), “Techno-economic feasibility study of the integration of a commercial small-scale ORC in a real case study”, Energy Conversion and Management, 99, 161-175. - Pérez-Díaz, J. I., Chazarra, M., García-González, J., Cavazzini, G., Stoppato, A. (2015), “Trends and challenges in the operation of pumped-storage hydropower plants”, Renewable and Sustainable Energy Reviews, 44, 767-784. - Ardizzon, G., Cavazzini, G., Pavesi, G. (2014), “A new generation of small hydro and pumped-hydro power plants: Advances and future challenges”, Renewable and Sustainable Energy Reviews, 31, 746-761.
Additional information	

Course unit English denomination	**Tutela della proprietà intellettuale**
SS	-
Teacher in charge (if defined)	
Teaching Hours	20
Number of ECTS credits allocated	4
Course period	1-2-3 year February - March
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to the legislation applicable to patents, utility models and trade secrets with a focus on patents (patentable items, criteria for patentability, process for granting, ownership and circulation of patent rights, enforcement of patent rights)
Learning goals	Providing students with knowledge on the available legal tools for the protection and exploitation of technological innovation
Teaching methods	Providing students with knowledge on the available legal tools for the protection and exploitation of technological innovation
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	

Examination methods (if applicable)	Final evaluation will be based on written questionnaire with open questions
Suggested readings	- VANZETTI – DI CATALDO, Manuale di diritto industriale, Giuffré (2021), pp. 375-500 - Slides prepared by the lecturer to be provided to student
Additional information	

Course unit English denomination	**Yield criteria for polymer materials**
SS	
Teacher in charge (if defined)	
Teaching Hours	10
Number of ECTS credits allocated	2
Course period	1 year February
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (Attendance is required for at least 2/3 of the course) ☐ No
Course unit contents	Introduction to polymer materials Stress-strain curve. Tensile and compressive static tests according to International Standards. Macroscopic and microscopic yielding: damage mechanisms. Definition of multiaxial stress state: octahedral normal and tangential stress components Yield criteria for macroscopic yielding: Bauwens criterion, Raghava Caddel Yeh criterion. Yield criteria for microscopic yielding: Sternstein criterion. Strain Energy Release Rate: definition, experimental evaluation according to the International Standards. The Bucknall criterion Examples
Learning goals	At the end of the course, the PhD student will be able to classify polymeric materials and, consequently, use the most appropriate criteria for estimating their static strength, even in the presence of stress-concentration phenomena.
Teaching methods	At the end of the course, the PhD student will be able to classify polymeric materials and, consequently, use the most appropriate criteria

	for estimating their static strength, even in the presence of stress-concentration phenomena.
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	Final evaluation will be based on written questionnaire with open questions
Suggested readings	- Raghava et al, J Mater Science 1973 - Bucknall, Polymer 48, 2007
Additional information	