Syllabus

Course Description

Course Title	Electric and hybrid mobility
Course Code	45541
Course Title Additional	
Scientific-Disciplinary Sector	
Language	English
Degree Course	Master in Energy Engineering
Other Degree Courses (Loaned)	
Lecturers	Dr. Jacopo Carlo Alberizzi, JacopoCarlo.Alberizzi@unibz.it https://www.unibz.it/en/faculties/engineering/academic-staff/person/38725
Teaching Assistant	
Semester	Second semester
Course Year/s	Opt.
CP	6
Teaching Hours	36
Lab Hours	24
Individual Study Hours	0
Planned Office Hours	18
Contents Summary	The course of Electric and Hybrid Mobility is an elective course in the Energy Engineering degree. The course aims to introduce students to the novel technologies used for powertrains in the automotive sector for light/heavy duty vehicles that are moving towards electrification, in order to meet the stringent requirements in terms of emissions and performance.
Course Topics	The "Hybrid and electric mobility" course consists in two modules, 3 ECTS each. The "Electric powertrains and batteries" module is intended to give

	the students an overview of the current and promising solutions for electric and hybrid vehicles, comprising aspects related to electro mechanical power conversion, power converters and batteries. The course will cover the following topics: - Typical motors and drives used in electric cars, their requirements and figures of merit - Basics of electric power converters used in electric cars The module "Internal combustion engines for hybrid powertrains" focuses on the use of internal combustion engines in the hybrid and electric powertrains and their coupling to supply the required torque and power. The contents of the course will be useful for all the professional tasks, in the industry or in the public administration, related to the automotive sector. Typical jobs can be related to the design and performance assessment of novel powertrains, the development of the charging infrastructure and the electrochemical storage systems. These competences are necessary in the utilities' companies and in the industries designing components and solutions for powertrains.
Keywords	Powetrains, Hybrid vehicles, Electric vehicles, Clean mobility, Internal combustion enegines, Batteries.
Recommended Prerequisites	"Power Production, CHP and District Heating Systems", "Electric Power Conversion Equipment".
Propaedeutic Courses	
Teaching Format	The Course topics will be presented by the professors using electronic slides, blackboard. There are also classes (exercises) that will show practical applications of the theoretical topics in which calculus sheets and coding (Matlab/Python) will be used. Course topics will be presented using electronic slides. Teaching material and additional materials will be provided by the Professor during the semester in shared folders.
Mandatory Attendance	Not mandatory, but strongly advisable.
Specific Educational Objectives and Learning Outcomes	The course of Electric and Hybrid Mobility is an elective course in the Energy Engineering degree. The course aims to introduce students to the novel technologies used for powertrains in the

	automotive sector for light/heavy duty vehicles that are moving towards electrification, in order to meet the stringent requirements in terms of emissions and performance. The course consists of two modules: the first one is specifically focused on electric motors for the automotive industry, battery storage systems and related power converters; the second one is mainly focused on the use of internal combustion engines in the powertrains and their coupling with electric drives in Hybrid Electric Vehicles. Module A: Internal combustion engines for hybrid powertrains This module focuses on the use of internal combustion engines in the hybrid and electric powertrains and their coupling to supply the required torque and power. Specific educational objectives: - Understand the characteristics and the advantages of electric and hybrid powertrains vs. their conventional counterparts (ILO1) - Define modern and promising future solutions for the internal combustion engines used in hydrid vehicles or as range extenders (ILO2) - Applying knowledge to define the constraints in the sizing of electric motor(s), battery and combustion engine for hybrid and electric vehicles (ILO3) - Making judgements to define the most appropriate management solutions of the powertrain depending on the application (ILO4) - Describe with the correct terminology and with the correct parameters the performance of hybrid and electric vehicles (ILO5) - Learning skills to update the competences following the technical development of powertrains and storage systems (ILO6) Module B: Electric power trains and batteries Specific educational objectives: - Understand the characteristics and the advantages of electric and hybrid powertrains vs. their conventional counterparts (ILO1) - Define modern and promising future solutions for the internal

	combustion engines used in hybrid vehicles or as range extenders (ILO2) - Understand the advantages and disadvantages of different solutions for hybrid and electric powertrains (ILO3) - Understand the constraints in the sizing of electric motor(s), battery and combustion engine for hybrid and electric vehicles (ILO4) - Describe the principles of battery storage operation and the key performance parameters (ILO5) - Define the management criteria and control methods for hybrid powertrains (ILO6) Learning outcomes: Knowledge and understanding: The course allows the students to acquire advanced knowledge on the main solutions for the powertrains in the transport sector with specific focus on hybrid and electric cars. The topics presented will provide the basis for a thorough understanding of the architectures, of the design approaches and of the modelling of modern powertrains and battery systems used in the automotive sector. Applying knowledge and understanding: The student will be able to apply the acquired knowledge during exercises, where the studied models will be used to assess specific practical problems. Students will also apply the theoretical contents by using calculation codes and numerical models of the studied powertrains, storage systems and battery management systems. Making judgments: The student should acquire the ability to evaluate and compare different powertrain solutions, considering the overall architecture, the main components ad their management. The student should also be able to discuss and correlate the numerical results with the physical problem. Communication skills: The student should acquire the proper technical language and should be able to present design choices, and numerical results

	with a critical approach. Learning skills: The student should acquire lifelong learning skills through the possession of the tools to update knowledge on the powertrains in the automotive sector and the battery systems. Moreover, the student should be able to get the required data and information from databases, technical and scientific papers.
Specific Educational Objectives and Learning Outcomes (additional info.)	
Assessment	The final exam consists in a written exam (in combination with the other module of the course) on the topics of the course. The exam consists in 2 open questions per each course module on the theoretical concepts; in addition, it is asked to propose a possible powertrain architecture for a given application, indicating the main sizing of the powertrain and the control logic. Assessment language: English Summative assessment ILOs assessed Theory questions: 2x2 open-end questions. ILO assessed (1, 2, 6) Application: propose a design strategy of a powertrain and its management strategy, based on the final application (passenger vehicle, heavy-duty powertrain, etc.). ILO assessed (3,4,5) Total duration: 1,5 hours.
Evaluation Criteria	The student must demonstrate to have acquired the fundamental principles and the theoretical basis required in the design of modern and electrified powertrains; moreover, the student must show the ability to apply the knowledge in practical test cases. In order to get a positive final mark, the student must demonstrate understanding of all the basic knowledge presented in the course. The maximum evaluation is achieved by demonstrating in-depth knowledge.

	For the evaluation of the oral exam the following criteria will be taken into account: - Ability to describe the powertrain architectures and design solutions of internal combustion engines, electric drives and storage systems. -Ability to model the single systems presented in the lectures and in the exercises. - Ability to approach a basic design of a modern powertrain. - Ability to provide examples/applications of the theoretical concepts. - Proper use of the technical language.
Required Readings	The slides presented during the lectures will be available in the course Teams. Any additional required material will be supplied during the lectures and made available to the students (Matlab/phyton codes, etc.).
Supplementary Readings	
Further Information	Connections with other courses: The course "Electric and hybrid mobility" integrates the content of previous courses related to power conversion and internal combustion engines, namely the module of Thermal Engines, and to electric machines and power converters, namely the course of Electric Power Conversion Equipment. It is also correlated energy storage topics presented in the course of Electrochemical Energy Storage and Conversion. On a broader perspective and considering the vehicle-to-grid-applications, the course is also correlated to the course of Smart Grids. Professional applications of the covered topics: The topics presented in this course can be applied in all those industrial job functions involving the design and control of powertrains for passenger and industrial vehicles. In particular, the choice of the main powertrain components and management of the energy flows can be addressed depending on specific design goals and constraints related to performance, range and efficiency. Also consultancy on the broad automotive sector can be addressed with the competences acquired in this course.
Sustainable Development Goals (SDGs)	Affordable and clean energy, Industry, innovation and infrastructure, Climate action, Responsible consumption and production, Sustainable cities and communities

Course Module

Course Constituent Title	Internal combustion engines for hybrid powertrains
Course Code	45541A
Scientific-Disciplinary Sector	IIND-06/A
Language	English
Lecturers	
Teaching Assistant	
Semester	Second semester
CP	3
Responsible Lecturer	
Teaching Hours	18
Lab Hours	12
Individual Study Hours	45
Planned Office Hours	9
Contents Summary	The Internal combustion engines for hybrid powertrains module is intended to give the students an insight of the novel design solutions in powertrains for the transport sector with a specific focus on the coupling of internal combustion engines to electric drives and their management.
Course Topics	The course will cover the following topics: - Vehicles and Powertrains, vehicle motion and force calculations - Combustion Engine Powertrains and mechanical power transmission - Typology of batteries, their operation and performance in electric and hybrid cars - Series and parallel hybrid vehicles, Plug-in vehicles - Mechanisms for torque/power sharing in HEVs - Driving Cycles and Fuel Consumption The contents of this module will be useful for all the professional tasks, in the industry or in the public administration, related to the automotive sector. Typical jobs can be related to the design and performance assessment of novel powertrains, the development of the charging infrastructure and the electrochemical storage systems. These competences are necessary in the utilities'

	companies and in the industries designing components and solutions for powertrains.
Teaching Format	The course consists of lectures in which the topics are presented by the professor. There are also classes (exercises) that will give practical examples of the application of the theoretical topics. Course topics will be presented using electronic slides. Teaching material and additional materials will be provided by the Professor during the semester.
Required Readings	The slides presented during the lectures will be available in the course Teams. Any additional required material will be supplied during the lectures and made available to the students (Matlab/phyton codes, etc.)
Supplementary Readings	

Course Module

Course Constituent Title	Electric powertrains and batteries
Course Code	45541B
Scientific-Disciplinary Sector	IIND-08/A
Language	English
Lecturers	
Teaching Assistant	
Semester	Second semester
CP	3
Responsible Lecturer	
Teaching Hours	18
Lab Hours	12
Individual Study Hours	45
Planned Office Hours	9
Contents Summary	The Electric powertrains and batteries module is intended to give the students an overview of the current and promising solutions for electric and hybrid vehicles, comprising aspects related to electro-mechanical power conversion, power converters and batteries.
Course Topics	The course will cover the following topics: - Typical motors and drives used in electric cars, their requirements and figures of merit

	- Basics of power converters used in electric cars - Typology of batteries, their operation and performance in electric cars.
Teaching Format	The course consists of lectures in which the topics are presented by the teacher. There are also classes (exercises) that will give practical examples of the application of theoretical topics. Course topics will be presented on the blackboard and using electronic slides. Teaching material and additional materials will be provided by the teacher during the semester.
Required Readings	The slides presented during the lectures, provided during the course and available in the reserve collection. Any additional required material will be supplied during the lectures and made available in the reserve collection.
Supplementary Readings	Optimization and Optimal Control in Automotive Systems - Harald Waschl, Ilya Kolmanovsky, Maarten Steinbuch, Luigi del Re