| n. | Teaching Activity | Total number of hours over the entire cycle | Distribution during the PhD cycle (years in which the teaching is active) | Course description | Possible reference curriculum | Final assessment |
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| 1. | Artificial Intelligence Algorithms and Machine Learning Techniques | 14 | First Year | This course covers data analysis and Machine Learning techniques in MATLAB® using the functionality offered by the Statistics and Machine Learning Toolbox™ and Deep Learning Toolbox™. The course illustrates the use of unsupervised learning to detect features in large datasets and supervised learning to develop predictive models. Examples and exercises highlight useful techniques for visualising and evaluating results, with particular reference to engineering applications. List of topics:<br>- Image processing with MATLAB<br>- Machine Learning and Deep Learning with MATLAB<br>- Implementation of Machine Learning techniques in Simulink | ENERGY SYSTEMS, POWERTRAINS, VEHICLE PERFORMANCE VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION VEHICLE INFORMATICS AND CONNECTIVITY | YES |
| 2. | Reduction of CO2 emissions for automotive powertrains | 18 | Second Year | The course will present the main technologies currently used and under development for reducing the environmental impact of vehicle propulsion systems with particular reference to CO2 emissions. The course will be divided into modules covering the following topics: optimisation of the efficiency of traditional, electric and hybrid powertrain components (electric motor, thermal motor, inverter and battery); general sizing criteria and control strategies for hybrid powertrains (MHEV, FHEV, PHEV); use of alternative low-carbon and bio-fuels. | ENERGY SYSTEMS, POWERTRAINS, VEHICLE PERFORMANCE | YES |

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| | | | | A project is assigned at the end of the course, which serves as the final assessment. | | |
| 3. | Advanced materials and manufacturing technologies for Automotive | 18 | Second Year | In the automotive industry, additive manufacturing has played a key role as a prototyping technology in the past. With the advancement of technology, however, the possibility of using additive technologies for series production of components is becoming increasingly important. Various aspects of additive manufacturing will be covered in the proposed course, in particular:<br>- Automotive - development processes and intellectual property<br>- technological aspects of additive manufacturing of metals: process overview, potential and challenges<br>- metallurgical aspects of metals processed using additive technologies: raw materials, microstructure, post-process heat treatments and mechanical properties<br>- topological optimisation for advanced manufacturing<br>- design guidelines for additive manufacturing<br>- design and qualification of automotive components produced by additive manufacturing.<br>A project is assigned at the end of the course, which serves as the final assessment. | VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION | YES |
| 4. | Connected and Autonomous Vehicles | 18 | Second Year | The course aims to train PhD students in ICT and its applications to the automotive world. This course will focus on the research topics of the lecturers and groups involved in the PhD board. In particular, the course will be structured into 6 | VEHICLE INFORMATICS AND CONNECTIVITY | YES |

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| | | | | monothematic lectures of 3 hours on the following topics:<br>- Direct V2X communications, with focus on ETSI C-ITS<br>- 5G and 6G cellular communications for V2X<br>- Intra-vehicle communications for self-driving cars<br>- Overview of ADAS systems<br>- Example use cases: CACC (Cooperative Adaptive Cruise Control) systems and coordination of multi-vehicle systems at traffic junctions. Theory and experiments<br>- High-performance monitoring of road pavements through connected vehicles.<br><br>At the end of the course, a project is assigned to serve as a final assessment. | | |
| 5. | Data-driven methods in engineering | 12 | First Year Third Year | The course consists of 12 hours of lectures and aims to provide the main elements concerning machine learning techniques for modelling complex dynamic systems. The course is divided into the following main phases:<br>1) Introduction. The singular-value decomposition (SVD)<br>2) Compressed sensing, optimal sensor placement<br>3) Robust principal component analysis and dynamic-mode decomposition (DMD)<br>4) Implementation of modal decompositions<br>5) Deep-learning applications and developments<br><br>Theoretical/practical exercises are offered during the course. Applications are also developed for the application of machine | ENERGY SYSTEMS, POWERTRAINS, VEHICLE PERFORMANCE VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION VEHICLE INFORMATICS AND CONNECTIVITY | YES |

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| | | | | learning techniques to simplified models. At the end of the course, a project is assigned, which serves as a final assessment. | | |
| 6. | The Craft of Scientific Research | 36 | First year | The craft of Scientific Research focuses on a set of transferable skills that are deemed essential for the practice of scientific research. The first part of three lectures focuses on the fundamental concept of scientific truth and how humanity pursues it: Why do we need to know? What is a model? How do we know? Then we deliver a long list of "how to" lectures: How to choose a research topic, write and publish a scientific paper, write a grant application, give a scientific presentation, build and run a research group, teach science at the university level, review a paper or a grant. Grant writing and peer reviewing will also be the subject of two tutorials and two individual projects; their completion will be required to pass the exam. | ENERGY SYSTEMS, POWERTRAINS, VEHICLE PERFORMANCE VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION VEHICLE INFORMATICS AND CONNECTIVITY | YES |
| 7. | Short course on Design of Experiments | 12 | First year | This course on Design of Experiment (DOE) consists of several lectures for a total of 12 hours. The first part deals with some fundamentals on DOE and the application of related techniques to different fields (not only technological) and, in general, to everyday life. It also discusses the importance of initial brainstorming, aimed at choosing the input and output variables and the most suitable technique regarding the specific field. Theoretical topics include one- and two-factor analysis of variance (ANOVA), the concept of interaction, pairwise | ENERGY SYSTEMS, POWERTRAINS, VEHICLE PERFORMANCE VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION VEHICLE INFORMATICS AND CONNECTIVITY | YES |

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| | | | | comparison tests, orthogonality and multifactor design.<br>The second part of the course focuses on applications of the above techniques in the field of engineering (in particular, mechanical design, additive manufacturing and joining techniques). Students will also have the opportunity to see some hints of the multidisciplinary applications of DOE.<br>At the end of the course, a couple of hours will be devoted to the interactive development of an experiment, the evaluation of which will constitute the final test for the award of credit. | | |
| 8. | Uncertainty Analysis for Engineers | 12 | First year | The course consists of 12 hours of lectures and 4 hours of practical exercises. In the beginning, the basic concepts, fundamental definitions, and different approaches commonly used for this purpose are presented. Afterwards, a mainly theoretical part develops the basic equations and statistical tools needed to characterise uncertainty. The theoretical part is then followed by an operational part in which the different operational methodologies for quantifying error are described.<br>Theoretical/practical exercises are proposed during the course. A matlab program is also developed for studying error propagation using Monte-Carlo methodologies. At the end of the course, a small project is assigned as a final check. | ENERGY SYSTEMS, POWERTRAINS, VEHICLE PERFORMANCE VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION VEHICLE INFORMATICS AND CONNECTIVITY | YES |
| 9. | Perturbation Methods in Mechanics | 12 | Second year | The course consists of 12 hours of lectures and 4 hours of practical exercises. The course aims to integrate the mathematical knowledge of PhD students by providing them with the fundamental rudiments of | ENERGY SYSTEMS, POWERTRAINS, VEHICLE | YES |

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| | | | | perturbation methods applied to physics and engineering.<br>Solutions of differential equations to ordinary derivatives are analysed by specialising them for one-parameter problems. The course is structured in the following parts:<br>1) Basic concepts of perturbation techniques, such as order relationships, asymptotic sequences, asymptotic expansions and convergence issues<br>2) solution method for regular perturbation problems<br>3) regular and a singular perturbation problem<br>4) balancing method and boundary-layer theory<br>5) inner and outer solutions for singular perturbation problems by means of boundary-layer theory and the composite form.<br>6) multiple-scale analysis on linear and non-linear problems.<br><br>Theoretical/practical exercises are offered during the course and a small project is assigned at the end as a final check. | PERFORMANCE VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION VEHICLE INFORMATICS AND CONNECTIVITY | |
| 10 | Python programming for scientific research | 12 | First Year | This course offered to PhD students covers some aspects of open-source programming tools within Python environment. In particular, this course will provide the essential skills to develop scripts and platform-independent applications for various engineering applications. The basis of Python programming will be introduced, such as variables declaration and initialization, construction of expressions with | ENERGY SYSTEMS, POWERTRAINS, VEHICLE PERFORMANCE VEHICLE DESIGN, MANUFACTURING AND SYSTEMS INTEGRATION | YES |

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| | | | | arithmetic, logical and relational operators. Then, plotting and image analysis tools will be explored. Finally, manipulation techniques of texts and files will be explored, with application to specific examples in engineering. In the end, open-source programming skills in Python will be achieved and practiced by the PhD students. | VEHICLE INFORMATICS AND CONNECTIVITY | |