Course guide
295810 - 295HY031 - Low Temperature Fuel Cell Systems Engineering

Last modified: 02/10/2025

Unit in charge: Barcelona East School of Engineering
Teaching unit: 729 - MF - Department of Fluid Mechanics.

Degree: ERASMUS MUNDUS MASTER IN HYDROGEN SYSTEMS AND ENABLING TECHNOLOGIES (HYSET) (Syllabus 2024). (Optional subject).
MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Optional subject).
MASTER'S DEGREE IN TECHNOLOGIES FOR DISTRIBUTED ENERGY SYSTEMS (Syllabus 2025). (Optional subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: ATTILA PETER HUSAR

Others: Primer quadrimestre:
ATTILA PETER HUSAR - Grup: M11
VICENTE RODA SERRAT - Grup: M11

PRIOR SKILLS

Basic knowledge of chemical engineering, thermodynamics, heat transfer, fluid mechanics and process engineering

LEARNING RESULTS

Knowledges:
K4. Identify methods for studying the environmental impact of a distributed electricity system with renewable sources and relate it to the decarbonisation of energy generation.
K2. Identify the structural and functional particularities and applicable regulations of decentralised electrical systems.
K.06. Identify the most appropriate techniques, components and materials for the development of advanced applications in mechanical engineering.
K.01. Critically interpret the physical principles governing the behaviour of systems and advanced applications in the fields of mechanical design, manufacturing processes, strength of materials, fluid mechanics, thermodynamics and heat transfer.
K.08. Identify data analysis tools to characterise, synthesise, explain and predict the behaviour of physical systems in the field of mechanical engineering.
K.09. Identify appropriate measuring devices for characterising the behaviour of systems of interest in mechanical engineering.
K.04. Correctly interpret technical documentation related to the design of facilities, processes and products in the context of research and development projects in the mechanical engineering field.
K.05. Identify emerging technologies, both in the mechanical domain and in the field of new information and communication technologies, that can be applied to mechanical engineering projects.
K.02. Identify the fundamental equations governing physical phenomena associated with complex problems in mechanical engineering.
K.07. Define appropriate analytical, experimental and/or computational models to study relevant problems in mechanical engineering.
K01. Conceive, analyse, design, size, optimise and exploit hydrogen technologies and processes, with a focus on both technology and systems.
K02. Demonstrate in-depth knowledge of standards related to the safety of working with hydrogen, the integration of systems related to hydrogen technologies, and market potential.

Skills:

S3. Assess the impact and needs of new electricity consumption models and relate them to the change in energy model resulting from the decarbonisation of energy sources.
S.02. Correctly apply the analytical, computational and/or experimental techniques best suited to the analysis of a case or project in the mechanical field.
S.08. Integrate knowledge from different areas of the mechanical field in the design and development of projects, systems and engineering solutions.
S.04. Incorporate sustainability and energy efficiency criteria into the design, planning, execution and operation phases of engineering projects.
S.05. Critically examine the results of the analysis of a process or product, taking into account the limitations of the techniques used.
S.07. Design flexible production/operation systems to improve the performance of industrial processes.
S.01. Comprehensively apply experimental techniques, calculations, evaluations, appraisals, expert reports, studies, work plans and related tasks in the development of mechanical engineering projects, applying compulsory specifications, regulations and standards at each stage of the process.
S.03. Use advanced numerical simulation and virtual prototyping techniques to solve complex mechanical problems.
S04. Apply an understanding of advanced digital technologies with a critical perspective in a range of academic, professional, social and personal contexts, such as data analysis, multiscale modelling, techno-economic analysis and environmental systems analysis.
S01. Communicate effectively with others orally, in writing and graphically about learning, thought processes and decision making, and participate in discussions, using interpersonal skills such as active listening and empathy that support teamwork.
S02. Work in the field as well-trained, enthusiastic professionals with a broad multidisciplinary knowledge of hydrogen technologies and systems, educated in an international and multicultural environment to promote global cooperation in meeting the complex challenges of the energy transition.
S03. Contribute to innovation in new and existing institutions and business organisations through participation in creative projects, and apply skills and knowledge in entrepreneurship, organisation and technology-based business development.

Competences:

C1. Integrate the values of sustainability and understand the complexity of systems, with the aim of undertaking or promoting actions that restore and maintain the health of ecosystems and improve justice, thereby generating visions of sustainable futures.
C.03. Manage the acquisition, structuring, analysis and visualisation of data and information in the mechanical field and critically evaluate the results of this process.
C.02. Work as part of a multidisciplinary team, whether as a team member or in a leadership role, to contribute to the development of projects with pragmatism and a sense of responsibility, undertaking commitments with due regard to the resources available.
C.01. Recognise the complexity of the economic and social phenomena typical of a welfare society in order to relate welfare to globalisation and sustainability, and use techniques, technology and principles of economics and sustainability in a balanced and compatible way.
C.04. Ensure, within the limits of one’s professional competence, compliance with ethical standards, professional guidelines and current legislation regarding fundamental rights, taking into account the goal of reducing inequalities, the gender perspective, and the principles of accessibility, inclusion and non-discrimination in the design of technical solutions and in the management of projects and teams.
C.05. Propose advanced scientific and technological solutions to complex industrial challenges in the field of mechanical engineering.
C05. Propose advanced scientific and technological solutions to complex industrial challenges in the field of energy, with a focus on the use of hydrogen as a vector.
C02. Work as part of a multidisciplinary team, whether as a team member or in a leadership role, to contribute to the development of projects with pragmatism and a sense of responsibility, undertaking commitments with due regard to the resources available.

TEACHING METHODOLOGY

- Lectures and conferences: knowledge exposed by lecturers or guest speakers.
- Participatory sessions: the collective resolution of exercises, debates, and group dynamics, with the lecturer and other students in the classroom; classroom presentation of an activity individually or in small groups.
- Theoretical/practical supervised work: classroom activity, carried out individually or in small groups, with the advice and supervision of the professor.
- Homework assignments of reduced extension: carry out homework of reduced extension, individually or in groups.
- Group projects assignment of broad extension: design, planning and implementation of a project or homework assignment of broad extension by a group of students, and writing a report that should include the approach, results and conclusions.

LEARNING OBJECTIVES OF THE SUBJECT

- To develop scientific and technical skills to design and test low-temperature fuel cells, and to set up the basis for their implementation, optimization and/or modification.
- To develop technical criteria to define and select a low-temperature fuel cell system with the participation of other energy devices (fuel processing, hybridization with other energy storage devices e.i. batteries).
- To identify the problems and weaknesses of Polymer Electrolyte Membrane Fuel Cells (PEMFC), cells, stacks, balance of plant components, and systems configurations, and to provide engineering solutions.
- To develop scientific skills to develop new ideas related to low-temperature fuel cells.

STUDY LOAD

Type	Hours	Percentage
Hours small group	21,0	14.00
Self study	108,0	72.00
Hours large group	21,0	14.00

Total learning time: 150 h

CONTENTS

Topic 1. Introduction

Description:
Hydrogen economy, Fuel cells fundamentals.

Full-or-part-time: 3h 30m
Theory classes: 1h
Self study : 2h 30m

Topic 2. Thermodynamics and electrochemical kinetics

Description:
Operating characteristics of cells. Thermodynamic and electrochemical losses. Electrical efficiency and heat rejection. Cell performance variables.

Full-or-part-time: 7h 10m
Theory classes: 2h
Self study : 5h 10m

Topic 3. Fuel cell types and components

Description:
Polymer Electrolyte Membrane (PEM). Direct Menthol (PEM DMPEM). High-temperature PEM. Cell components, Stack components, Design trade-offs.

Full-or-part-time: 25h
Theory classes: 4h
Laboratory classes: 3h
Self study : 18h

Topic 4. Characterization and Effect of operation conditions on fuel cell performance

Description:
Description: Definition of operating conditions, What are the variables that can be manipulated to change the performance, What are the trade-offs

Full-or-part-time: 28h 30m
Theory classes: 5h
Laboratory classes: 3h
Self study : 20h 30m

Topic 5. Degradation of fuel cells PEMFC y DMFC

Description:
Description: Definition of operating conditions, What are the variables that can be manipulated to change the performance, What are the trade-offs

Full-or-part-time: 17h 50m
Theory classes: 5h
Self study : 12h 50m

Topic 6. System design

Description:
Types of systems, Design trade-offs

Full-or-part-time: 17h 50m
Theory classes: 5h
Self study : 12h 50m

Topic 7. System control strategies and design

Description:
Types of control strategies, Trade-off

Full-or-part-time: 28h 30m
Theory classes: 5h
Laboratory classes: 3h
Self study : 20h 30m

Topic 8. Fuel cell applications

Description:
Tema 8. Aplicacions de les piles de combustible

Full-or-part-time: 21h 40m
Theory classes: 6h
Self study : 15h 40m

GRADING SYSTEM

Continuous assessment (2 exams; 30% each written exam), laboratory reports (20%), and final group project (20%).

EXAMINATION RULES.

Written exams are individual. Laboratory and projects are carried out in groups.

BIBLIOGRAPHY

Basic:
- O'Hayre, Ryan P. Fuel cell fundamentals. Third edition. Hoboken, New Jersey: John Wiley & Sons, Inc, [2016]. ISBN 9781119113805.
- Dicks, Andrew L.; Rand, D. A. J. Fuel cell systems explained. Third edition. Hoboken, New Jersey: Wiley, 2018. ISBN 111870696X.
- Fuel cell handbook. Seventh edition. Virginia: National Energy Technology Laboratory, [2016]. ISBN 9781365101137.
- Barbir, Frano. PEM fuel cells : theory and practice. Amsterdam: Elsevier Academic, 2005. ISBN 9780120781423.
- Santhanam, K. S. V.; Press, Roman J.; Miri, Massoud J.; Bailey, Alla V.; Takacs, Gerald A. Introduction to hydrogen technology. Second edition. John Wiley & Sons, 2017. ISBN 9781119265542.