UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
295104 - 295II014 - Systems Modelling

Last modified: 02/10/2025

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

Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Compulsory subject).
MASTER'S DEGREE IN MATERIALS SCIENCE AND ADVANCED MATERIALS ENGINEERING (Syllabus 2019). (Optional subject).
MASTER'S DEGREE IN RESEARCH IN MECHANICAL ENGINEERING (Syllabus 2021). (Optional subject).
ERASMUS MUNDUS MASTER IN SUSTAINABLE SYSTEMS ENGINEERING (EMSSE) (Syllabus 2024). (Optional subject).
MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Optional subject).

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

LECTURER

Coordinating lecturer: RICARDO JAVIER PRINCIPE RUBIO

Others: Primer quadrimestre:
FERNANDO GARCIA GONZALEZ - Grup: T1
ALFREDO DE JESUS GUARDO ZABALETA - Grup: T1, Grup: T2
LLUÍS JOFRE CRUANYES - Grup: T1
RICARDO JAVIER PRINCIPE RUBIO - Grup: T1

PRIOR SKILLS

Calculus. Basic knowledge of differential equations.
Fluid mechanics, heat transfer.
Computer usage, notions of programming

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMUEII-04. Design and implement modeling techniques to describe the operation of a system. Predict its stability and apply control techniques in different scenarios.
CEMCEAM-02. (ENG) Aplicar métodos innovadores para el diseño, simulación, optimización y control de procesos de producción y transformación de materiales
CEMCEAM-07. (ENG) Gestionar la Investigación, Desarrollo e Innovación Tecnológica, atendiendo a la transferencia de tecnología y los derechos de propiedad y de patentes

Generical:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

LEARNING RESULTS

Knowledges:
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.
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.

Skills:
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.03. Use advanced numerical simulation and virtual prototyping techniques to solve complex mechanical problems.
S.05. Critically examine the results of the analysis of a process or product, taking into account the limitations of the techniques used.
S.06. Efficiently manage information collected during analytical, numerical and/or experimental studies and automate its analysis to facilitate knowledge extraction.

Competences:
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.05. Propose advanced scientific and technological solutions to complex industrial challenges in the field of mechanical engineering.
C03. Manage the acquisition, organisation, analysis and presentation of data and information in the field of complex systems engineering and critically assess the results obtained.
C02. Work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.
C05. Propose advanced scientific and technological solutions to complex industrial challenges in areas such as intelligent production, robotic systems, logistics, fault detection and predictive maintenance.

TEACHING METHODOLOGY

The hours of driven activities in large groups will be theoretical classes with an expository and participatory approach.
The hours of activities directed in small groups will be devoted to the resolution of exercises and the computational simulations systems (in computer rooms) using commercial and open source software.
The hours of autonomous learning will be devoted to the study of theory, the solution of problems and computer simulations of systems.

LEARNING OBJECTIVES OF THE SUBJECT

- Understand models of physical systems based on partial differential equations, continuum mechanics and constitutive models.
- Understand the concept of weak solutions of partial differential equations, which are key to describe several physical phenomena (e.g. shock waves).
- Understand the concept of regularity of these solutions and how it determines the difficulty of the problem (e.g. the computational cost of numerical simulations).
- Understand the weak formulation of physical laws and the continuity conditions they imply when dealing with multiphysics problems.
- Identify multi-scale features of physical problems, select appropriate scale separation operators and small scale models.

STUDY LOAD

Type	Hours	Percentage
Hours large group	27,0	18.00
Self study	96,0	64.00
Hours small group	27,0	18.00

Total learning time: 150 h

CONTENTS

Mathematical modeling of systems

Description:
Introduction to systems modeling
Description of systems
Constitutive modeling
Some simple models

Specific objectives:
Understand different levels of descriptions of physical systems and strategies for their modeling.
Learn continuum mechanics basis, constitutive modeling and possible simplifications.

Related activities:
A1 Computational modeling of laminar flows (flow past a cytlinder, airfloil, driven cavity, etc.)

Full-or-part-time: 20h
Theory classes: 6h
Laboratory classes: 2h
Self study : 12h

Classical theory of partial differential equations

Description:
Introduction to partial differential equations
First and second order partial differential equations
Fundamental solutions and their properties
Green identities and Green functions

Specific objectives:
Learn basic concepts of partial differential equations (order, lineraity, type)
Understand properties of classical solutions (uniqueness, mean value, maximum principle, etc.), including regularity.

Related activities:
B1 Computational modeling of partial differential equations with regular solutions

Full-or-part-time: 42h
Theory classes: 10h
Laboratory classes: 2h
Self study : 30h

General theory of partial differential equations

Description:
Nonlinear first order partial differential equations, shock waves
Distributions and weak derivatives
Functional spaces and weak formulation of partial differential equations
Numerical methods for partial differential equations

Specific objectives:
Understand the need for generalized solutions of partial differential equations
Learn the basis of weak derivatives, functional spaces and weak formulations
Understand the impact of regularity on the computational cost of numerical methods

Related activities:
B2 Computational modeling of partial differential equations with non-regular (weak) solutions
A2 Computational modeling of compressible flows (shock waves)

Full-or-part-time: 46h
Theory classes: 10h
Laboratory classes: 6h
Self study : 30h

Multiphysics and multiscale modeling

Description:
Transmission conditions in continuum mechanics.
Classical homogenization theory
Scale separation for nonlinear problems and small scale modeling

Specific objectives:
- Understand continuity conditions implied by the weak formulation of physical laws
- Identify multiscale features of phyisical problems and learn the basics of scale separation and small scale modeling
- Choose appropriate solution strategies for multiscale problems

Related activities:
A3 Computational modeling of fluid-structure interaction (airfloils, blood flows, aneurysms)
B3 Computational modeling of partial differential equations with multiscale features
A4 Computational modeling of turbulent flows

Full-or-part-time: 42h
Theory classes: 8h
Laboratory classes: 10h
Self study : 24h

GRADING SYSTEM

20% Basic computational lab sessions
20% Applications to systems modelling
20% Deliverable homeworks
40% Final exam

EXAMINATION RULES.

Individual exam; homeworks in groups of two people.

BIBLIOGRAPHY

Basic:

- Batchelor, G. K. An introduction to fluid dynamics. Cambridge: Cambridge University Press, 1973. ISBN 0521663962.
- Pope, S. B. Turbulent flows. Cambridge [etc.]: Cambridge University Press, 2000. ISBN 0521591252.
- Strauss, Walter A. Partial differential equations : an introduction. 2nd ed. Hoboken: John Wiley & Sons, 2008. ISBN 9780470054567.
- Pavliotis, Grigorios A; Stuart, Andrew M. Multiscale methods : averaging and homogenization [on line]. New York, NY: Springer New York, 2008 [Consultation: 24/04/2020]. Available on: http://dx.doi.org/10.1007/978-0-387-73829-1. ISBN 9780387738291.
- Evans, Lawrence C. Partial differential equations. 2nd ed. Providence, Rhode Island: American Mathematical Society, cop. 2010. ISBN 9780821849743.
- Ljung, Lennart; Glad, Torkel. Modeling of dynamic systems. Englewood Cliffs: PTR Prentice Hall, 1994. ISBN 0135970970.

Complementary:

- Malvern, Lawrence E. Introduction to the mechanics of a continuous medium. Englewood Cliffs, NJ: Prentice-Hall, cop. 1969. ISBN 9780134876030.
- Wilcox, David C. Turbulence modelling for CFD. 3rd ed. La Canada, Calif.: DCW Industries, cop. 2006. ISBN 9781928729082.