Course guide
34958 - MMPDE - Mathematical Modelling with Partial Differential Equations

Last modified: 22/05/2026

Unit in charge: School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics.
751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2026 **ECTS Credits:** 7.5 **Languages:** English

LECTURER

Coordinating lecturer: MATTEO GIACOMINI

Others: Primer quadrimestre:
JEZABEL CURBELO HERNANDEZ - A
MATTEO GIACOMINI - A
JOSE JAVIER MUÑOZ ROMERO - A

PRIOR SKILLS

Good knowledge of calculus techniques, including integral theorems. Elementary solution of ODEs and PDEs.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:
5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
7. 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.
8. 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.
9. 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.

TEACHING METHODOLOGY

The course mainly consists of theoretical lectures, but it also includes problem solving and computer sessions, with numerical codes provided to illustrate the behaviour of the models.

LEARNING OBJECTIVES OF THE SUBJECT

Many phenomena taking place in physical and engineering systems can be described by means of systems of partial differential equations (PDEs). This is, e.g., the case of heat transfer phenomena, contaminant transport, fluid dynamics, mechanics of complex media (inhomogeneous materials, metamaterials, …), and wave propagation, just to name a few. The module provides a general overview on the use of PDEs to construct mathematical models of physical phenomena and engineering systems.

The module aims to provide a first introduction to the mathematical tools to model physical phenomena, rigorously setting the governing equations describing the engineering systems under analysis. By the end of the module, students are expected to be able to:
- describe basic physical phenomena using PDEs;
- provide intuitive interpretation of the mathematical operators appearing in a PDE;
- predict the physical behaviour of an engineering system in view of its mathematical description using PDEs.

STUDY LOAD

Type	Hours	Percentage
Hours large group	60,0	32.00
Self study	127,5	68.00

Total learning time: 187.5 h

CONTENTS

Introduction

Description:
Motivation and examples. Review of fundamental mathematical tools for the module. Primal, dual, and mixed formulations.

Full-or-part-time: 6h
Theory classes: 6h

Potential theory

Description:
Potential energy. Classic gravitation. Electrostatics. Minimal surfaces.

Full-or-part-time: 6h
Theory classes: 6h

Potential flows

Description:
Ideal flows. Complex analysis theory. Conformal maps.

Full-or-part-time: 12h
Theory classes: 12h

Convection-diffusion-reaction phenomena

Description:
Fourier and Fick laws. Heat and diffusion equations. Random walks. Convection-diffusion-reaction equations. Turing patterns.

Full-or-part-time: 12h
Theory classes: 12h

Continuum mechanics

Description:
Conservation laws. Constitutive laws. Elasticity. Viscoelasticity.

Full-or-part-time: 6h
Theory classes: 6h

Fluid dynamics

Description:
Viscous incompressible flows. Highly viscous flows. Inviscid compressible flows.

Full-or-part-time: 12h
Theory classes: 12h

Porous media flow

Description:
Heterogeneous materials. Homogenisation theory. Darcy’s law.

Full-or-part-time: 6h
Theory classes: 6h

GRADING SYSTEM

The grade of the course is obtained from a continuous assessment during the module. This consists of several activities of incremental training, carried out during the module, both in and out of the classroom.

The final grade will be computed as follows:
- 35% exam 1;
- 35% exam 2;
- 30% continuous evaluation (assignments and exercises).

EXAMINATION RULES.

The assignments must be submitted via ATENeA by the announced deadline. Late submissions or assignments submitted using other means will not be accepted and will be graded 0. The assignments must be performed individually: students are encouraged to discuss about the assignments but the submitted work must be the result of one own effort. Plagiarism in the assignments will be punished with a 0 in the classwork grade.

The written exams must be performed individually and will be closed-book. Plagiarism will be punished with a 0 in the module grade.

BIBLIOGRAPHY

Basic:

- Salsa, Sandro. Partial differential equations in action : from modelling to theory [on line]. Milan [etc.]: Springer, cop. 2008 [Consultation: 07/07/2023]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3062992. ISBN 9788847007512.
- Howison, Sam. Practical applied mathematics : modelling, analysis, approximation. New York: Cambridge University Press, 2005. ISBN 0521603692.
- Ockendon, J.R. [et al.]. Applied partial differential equations. Revised ed. Oxford: Oxford University Press, 2003. ISBN 0198527713.
- Witelsky, T.; Bowen, M. Methods of mathematical modelling. Cham (Switzerland): Springer, 2015. ISBN 9783319230412.
- Chorin, A. J.; Marsden, J.E. A Mathematical introduction to fluid mechanics. 3rd ed. Springer, ISBN 978-0387979182.

Complementary:

- Friedman, A.; Litman, W. Industrial mathematics : a course in solving real-world problems. Philadelphia: SIAM, 1994. ISBN 0898713242.
- Fowler, A.C. Mathematical models in the applied sciences. Cambridge: Cambridge University Press, 1997. ISBN 0521467039.
- Dacorogna, Bernard. Introduction to the calculus of variations [on line]. 2015 [Consultation: 07/07/2023]. Available on: https://www-worldscientific-com.recursos.biblioteca.upc.edu/worldscibooks/10.1142/p967#t=toc. ISBN 9781783265534.
- LeVeque, Randall J. Finite difference methods for ordinary and partial differential equations : steady state and time-dependent problems [on line]. SIAM, 2007 [Consultation: 07/07/2023]. Available on: https://faculty.washington.edu/rjl/fdmbook/. ISBN 9780898716290.

RESOURCES

Other resources:

Teaching material including slides, class notes, lists of exercises are available on ATENeA.