UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Course guide
250COD003 - 250COD003 - Computational Fluid Dynamics

Last modified: 15/06/2026

Unit in charge: Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN COMPUTATIONAL AND DATA-ASSISTED ENGINEERING (Syllabus 2026). (Compulsory subject).

Academic year: 2026 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: JOAN BAIGES AZNAR

Others: MATTEO GIACOMINI
RAMON CODINA

PRIOR SKILLS

The course will be taught in english

TEACHING METHODOLOGY

The teaching methodology is based on 3 hours of face-to-face instruction per week, divided between lectures and practical sessions. The lectures are devoted to the presentation and development of the fundamental concepts of the course, providing the conceptual framework required to achieve the general and specific learning objectives.

The practical sessions focus on solving problems and applied exercises, following a participatory approach that promotes greater interaction with students. These activities help consolidate the concepts introduced during the lectures and develop the ability to apply them to specific situations.

All the necessary teaching materials (lecture notes, presentations, problem statements, and supplementary resources) are made available to students through the course learning platform. These materials support class attendance and facilitate students' independent learning.

LEARNING OBJECTIVES OF THE SUBJECT

The course covers the essential theoretical and practical aspects of the numerical approximation of partial differential equations for the description of compressible and incompressible flows, specifically the Euler and Navier–Stokes equations.

Learning objectives: to understand the fundamentals of the mathematical description of fluid motion, to develop numerical algorithms for the simulation of convection–diffusion–reaction phenomena, and to understand the numerical challenges and approximation techniques for incompressible flow problems (Stokes and Navier–Stokes equations) and inviscid flows (Euler equations). More specifically:

* Describe, predict, and formulate numerical techniques for steady linear convection–diffusion–reaction problems.
* Understand stabilization techniques for convection-dominated flows.
* Understand the main challenges in the approximation of hyperbolic equations and the concept of a well-posed Euler problem.
* Describe, predict, and formulate numerical techniques for incompressible flows.
* Understand the main challenges associated with the numerical solution of the Stokes and Navier–Stokes equations.

STUDY LOAD

Type	Hours	Percentage
Hours large group	45,0	36.00
Self study	80,0	64.00

Total learning time: 125 h

CONTENTS

Review of Basic Concepts

Description:
Description of the governing equations of fluid flow. Review of the fundamental equations of fluid mechanics. Reynolds, Prandtl, and Mach numbers. Weak form. Discretization. Element matrices and assembly. Numerical integration. Reference element. Implementation.

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

Steady Convection–Diffusion Problems

Description:
Analysis of the one-dimensional convection–diffusion equation. Effect of the Péclet number and the need for stabilization. Stabilization techniques. Consistent stabilized formulations. Extension to two- and three-dimensional problems. Practical exercises and implementation.

Full-or-part-time: 8h
Theory classes: 8h

Problema de Stokes

Description:
Stokes equations. Saddle-point problem. LBB condition. Stable and unstable spatial discretizations. Stabilization techniques. Consistent stabilized formulations.

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

Viscous Incompressible Flow Problems

Description:
Steady Navier–Stokes equations. Linearization techniques. Effect of the Reynolds number. Stabilization techniques. Transient Navier–Stokes equations. Time discretization. Algebraic splitting and fractional-step methods. Introduction to turbulence modelling. Practical exercises and implementation.

Full-or-part-time: 8h 30m
Theory classes: 8h 30m

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Compressible Flow Problems

Description:
Pure convection problems. Classical time and space discretization techniques: theta methods and Galerkin discretization. Nonlinear hyperbolic PDEs. Burgers' equation. Shock waves, rarefaction waves, and contact discontinuities. Entropy solutions. Basic properties of the Euler equations. Boundary conditions for hyperbolic PDEs. Riemann solvers. Finite volume discretization. Practical exercises.

Full-or-part-time: 8h
Theory classes: 8h

Other Discretization Methods

Description:
Discontinuous Galerkin methods, spectral methods, PFEM, and SPH.

Full-or-part-time: 6h 30m
Theory classes: 6h 30m

GRADING SYSTEM

The assessment system is based on a combination of examinations and practical assignments.

Examinations account for 80% of the final grade. Two midterm examinations are held during the course: the first contributes 60% of the examination grade, while the second contributes the remaining 40%.

Practical assignments account for 20% of the final grade and are intended to reinforce the learning of the course contents through their application to specific exercises or activities.

Students who do not pass the course through continuous assessment are entitled to take a final examination. This examination provides an opportunity to recover or assess the course contents as a whole, in accordance with the applicable academic regulations.

EXAMINATION RULES.

Assignments must be submitted through the ATENEA platform within the announced deadline. Late submissions or submissions sent through other means will not be accepted and will receive a grade of zero.

Assignments must be completed individually. Students are encouraged to discuss problems and exchange ideas, but the submitted work must be their own. Plagiarism in assignments will result in a grade of zero for the corresponding activity.

Written examinations must also be completed individually and will be closed-book. The use of textbooks and class notes is not permitted. Students may bring one DIN A4 formula sheet, handwritten on one side only. Plagiarism or any other form of academic misconduct during examinations will result in a final course grade of zero.

BIBLIOGRAPHY

Basic:
- Donea, Jean; Huerta, Antonio. Finite element methods for flow problems [on line]. Chichester: John Wiley & Sons,, 2003 [Consultation: 16/06/2026]. Available on: https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/0470013826. ISBN 0471496669.
- Volker, John. Finite element methods for incompressible flow problems [on line]. Cham: Springer, 2016 [Consultation: 16/06/2026]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-319-45750-5. ISBN 9783319457505.