



## Course guide

# 295451 - 295TM012 - Advanced Technologies in Fluid Science and Engineering

Last modified: 08/08/2024

**Unit in charge:** Barcelona East School of Engineering  
**Teaching unit:** 729 - MF - Department of Fluid Mechanics.  
**Degree:** MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Compulsory subject).  
**Academic year:** 2024    **ECTS Credits:** 6.0    **Languages:** Spanish

## LECTURER

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**Coordinating lecturer:** JAN MATEU ARMENGOL - FRANCESCO CAPUANO

**Others:** Primer quadrimestre:  
JOAN CALAFELL SANDIUMENGE - Grup: T1  
FRANCESCO CAPUANO - Grup: T1  
JAN MATEU ARMENGOL - Grup: T1  
RICARDO JAVIER PRINCIPE RUBIO - Grup: T1

## TEACHING METHODOLOGY

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The teaching methodology combines interactive frontal lectures (based on blackboard handwriting and dynamic, visually-supported presentations) with laboratory (tutorials + hands-on) sessions. During the class, students are constantly stimulated to engage in interactive discussions via practical examples, exploring real-world applications across various industries and fields. Theoretical lectures are closely integrated with hands-on experimental and computational labs, allowing students to actively participate in setting up experiments, collecting data, and analyzing results. Based on the teaching material and under the instructor's guidance, the students perform individual work to delve into the details of experimental and numerical tools/techniques utilized during the lab sessions, and to acquire related post-processing skills. Finally, a seminar series featuring guest lecturers provides insights into cutting-edge research and industry applications.

## LEARNING OBJECTIVES OF THE SUBJECT

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This course will equip students with the theoretical foundation as well as interpretive and predictive tools necessary for solving complex engineering problems related to fluid mechanics, preparing them for industrial applications or advanced applied research in mechanical engineering; nonetheless, the learning outcomes are transversal to fields such as aerospace, energy, environmental and biomedical engineering. At the end of the course, the students should be able to:

- Formulate and manipulate the mathematical equations that govern fluid flows across different flow regimes and in a wide range of physical complexity, and derive suitable approximations
- Identify, describe and characterize complex fluid mechanics phenomena that involve turbulent flows, fluid-structure interactions and multiphysics coupling
- Devise appropriate techniques (numerical, analytical or experimental) to address relevant fluid mechanics problems in complex engineering systems
- Possess an overview of the main experimental techniques to measure and visualize flow fields
- Set-up, run and analyze the results of a computational fluid dynamics (CFD) simulation using commercial software, and have a basic understanding of the related computational approach
- Critically interpret and analyze the results of experiments or computations, with awareness of the applicability and limitations of models/techniques employed
- Apply advanced fluid mechanics principles and tools to the design of real systems
- Describe current challenges in fluid dynamics and how they are being tackled



## STUDY LOAD

Type	Hours	Percentage
Self study	96,0	64.00
Hours large group	40,5	27.00
Hours small group	13,5	9.00

Total learning time: 150 h

## CONTENTS

### Fundamentals

**Description:**

Remarks on the governing equations of fluid flow and associated induced equations. Dimensionless numbers and flow regimes. Idealized models: irrotational flow, Stokes flow, incompressible flow and related approximations: low-Mach and Boussinesq models. Analytical solutions of steady and unsteady flows. Introduction to advanced models for describing complex and multi-physics flows discussed in the course, and related examples.

**Specific objectives:**

Command the governing equations of fluid flow, their mathematical structure and physical implications in a wide range of flow regimes and physical complexity. Refresh fundamental theoretical results and learn additional analytical tools to study fluid flow. Expand the knowledge of available analytical solutions of the Navier-Stokes equations.

**Related activities:**

Volumetric pump. Objectives of practical session: i) expand knowledge on turbomachinery; ii) analyze a low-Reynolds application with pulsatile flow and compare with analytical solution.

**Full-or-part-time:** 28h

Theory classes: 6h

Laboratory classes: 4h

Self study : 18h

### Visualization, measurement and prediction of flow fields

**Description:**

Limitations of theoretical models. Experimental approach: overview of flow visualization and measurement techniques. Experiments vs. computations. Introduction to computational fluid dynamics (CFD): overview of a numerical solution method.

**Specific objectives:**

Gather a basic understanding of modern tools and techniques to visualize and predict complex unsteady and three-dimensional flow fields both qualitatively and quantitatively; have a critical perspective on employing experimental vs. computational methods for studying fluid dynamics problems. Learn the basics of a CFD workflow.

**Related activities:**

Computational lab: Illustration of CFD software and setup of a simulation; post-processing and visualization of flow fields

Visualization/experimental lab: post-processing of experimental data

Objectives of practical session: i) learn how to set-up a CFD case; ii) visualize and manipulate experimental or computational flow datasets.

**Full-or-part-time:** 31h

Theory classes: 6h

Laboratory classes: 4h

Self study : 21h



### Turbulent flows

**Description:**

Flow instabilities and transition to turbulence. Phenomenology of turbulent flows and statistical description of turbulence. Free-shear turbulent flows: wakes, jets, mixing layers. External flows. Wall-bounded turbulent flows. Reynolds averaged equations and related stresses: the closure problem. Turbulence modeling.

**Specific objectives:**

Learn the phenomenology of unstable and turbulent flows in canonical configurations. Understand the difficulties associated with quantitative description of turbulence. Gather a basic grasp of turbulence modeling.

**Related activities:**

Experimental lab: turbulent flow using wind tunnel

Computational lab: RANS vs. LES/DNS simulation

Specific objectives of hand-on sessions: i) measure and analyze a turbulent signal; ii) understand the conceptual and practical difference between scale-resolving and Reynolds-averaged approaches; iii) compare experimental and numerical results; iv) learn how to visualize complex three-dimensional datasets.

**Full-or-part-time:** 33h

Theory classes: 10h

Laboratory classes: 4h

Self study : 19h

### Multi-physics flows

**Description:**

Introduction to multi-physics flows. Fluid-structure interaction in engineering and biological applications. Fundamentals of two-phase flows. Overview of reactive flows and coupling among energy, mass, and momentum transport equations. Data-driven modeling in fluid mechanics.

**Specific objectives:**

Acquire core competencies in the phenomenology and modeling of complex flows occurring in real-world industrial processes, including flows interacting with deformable structures, flows with a dispersed or stratified second phase, and flows with multi-physics. In addition, modern concepts of data-driven modeling are introduced.

**Related activities:**

Experimental lab: fluid-structure interaction experiment

Specific objectives of hands-on session: i) analyze experimental signals and extract relevant frequencies; ii) visualize phenomenology of FSI.

**Full-or-part-time:** 29h

Theory classes: 8h

Laboratory classes: 2h

Self study : 19h

### Project-based learning

**Description:**

Tutoring of the group project chosen by the students among those proposed.

**Full-or-part-time:** 29h

Guided activities: 10h

Self study : 19h



## GRADING SYSTEM

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Midterm theoretical test (30%)  
Laboratory performance (10%)  
Group project (60%)

## BIBLIOGRAPHY

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### Basic:

- Ferziger, Joel H; Peric, Milovan; Street, Robert L. Computational Methods for Fluid Dynamics . Fourth edition. Cham : Springer, [2019]. ISBN 9783319996912.
- Çengel, Yunus A; Cimbala, John M; Kanoglu, Mehmet. Fluid mechanics : fundamentals and applications . 2a ed. Boston [etc.] : McGraw-Hill, cop. 2010. ISBN 9780071284219.

### Complementary:

- Tritton, D. J. Physical fluid dynamics . 2nd ed. Oxford : New York : Clarendon Press ; Oxford University Press, cop. 1988. ISBN 9780198544890.
- Kundu, Pijush K; Cohen, Ira M; Hu, Howard H. Fluid mechanics . 2nd ed. San Diego [etc.] : Academic Press, cop. 2002. ISBN 9780121782511.
- Tavoularis, Stavros. Measurement in fluid mechanics . Cambridge [etc.] : Cambridge University Press, 2005. ISBN 9780521815185.
- Davidson, Peter. Turbulence : an introduction for scientists and engineers . Second edition. Oxford : Oxford University Press, [2015]. ISBN 9780198722595.
- Pope, S. B. Turbulent flows . Repr. with corr. Cambridge, UK [etc.] : Cambridge University Press, 2003. ISBN 9780521591256.