250954 - MECFLUID - Advanced Fluid Mechanics

**Coordinating unit:** 250 - ETSECCPB - Barcelona School of Civil Engineering  
**Teaching unit:** 751 - DECA - Department of Civil and Environmental Engineering  
**Academic year:** 2019  
**Degree:** ERASMUS MUNDUS MASTER'S DEGREE IN COMPUTATIONAL MECHANICS (Syllabus 2013). (Teaching unit Compulsory)  
MASTER'S DEGREE IN NUMERICAL METHODS IN ENGINEERING (Syllabus 2012). (Teaching unit Compulsory)  
**ECTS credits:** 5  
**Teaching languages:** English

**Coordinator:** PABLO SAEZ VIÑAS  
**Others:** MARCO DE CORATO, PABLO SAEZ VIÑAS

**Opening hours**

**Timetable:** Will be announced at the beginning of the course.

**Degree competences to which the subject contributes**

**Specific:**

8378. Practical numerical modeling skills. Ability to acquire knowledge on advanced numerical modeling applied to different areas of engineering such as: civil or environmental engineering or mechanical and aerospace engineering or bioengineering or Nanoengineering and naval and marine engineering, etc.

8379. Knowledge of the state of the art in numerical algorithms. Ability to catch up on the latest technologies for solving numerical problems in engineering and applied sciences.

8380. Materials modeling skills. Ability to acquire knowledge on modern physical models of the science of materials (advanced constitutive models) in solid and fluid mechanics.

8382. Experience in numerical simulations. Acquisition of fluency in modern numerical simulation tools and their application to multidisciplinary problems engineering and applied sciences.

8383. Interpretation of numerical models. Understanding the applicability and limitations of the various computational techniques.

8384. Experience in programming calculation methods. Ability to acquire training in the development and use of existing computational programs as well as pre and post-processors, knowledge of programming languages and of standard calculation libraries.

**Teaching methodology**

Taught module delivery: ten weeks of teaching, coursework and self-study, from October 13 to December 22. Apart from the 4 hours per week in the classroom, self-study must last an average of 8 hours per week minimum.

**Learning objectives of the subject**

The course provides the elements to understand the basic tools for the analysis and solution of different types of flows, from the ideal to the viscous flow, contrasting the numerical results with the experiments.

* The students will be able to understand and assimilate the foundations of fluid mechanics  
* The students will develop practical skills to work with tensors, formulate and develop analysis of diverse problems of solids and fluids in
The course includes six main topics:
* Basic concepts and reviews: Summary of vectorial analysis: classic theorems: Greens, Gauss, Stokes - derivative Eulerian/Lagrangian and Reynolds transport theorems.
* Characteristics and equations of compressible fluids.
* Nature of turbulences.
* Comparison of analytical, numerical, and experimental approaches to solve engineering problems.

Learning resources:

Learning objectives: to be able to understand
- the fundamentals of theoretical fluid mechanics: fluid's characteristics and equations of motion.
- the simplifications that can be made leading to models such as incompressible flow, inviscid flow, ideal fluid flow, boundary layer flow, irrotational flow, ...
- how classical solution techniques may be used to solve a range of problems involving these simplified flow problems.

Measurable outcomes: to be able to
- identify and solve basic fluid static problems
- obtain and solve Bernoulli's equations
- describe and deduce the potential flow equations and solve them for simplified cases
- select the appropriate boundary conditions and formulate the equations of fluid motion for compressible and incompressible Newtonian fluids
- write a problem in dimensionless form and select the appropriate dimensionless numbers.
## Study load

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<thead>
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<tbody>
<tr>
<td><strong>Total learning time:</strong></td>
<td>125h</td>
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<tr>
<td>Theory classes:</td>
<td>7h 30m</td>
<td>6.00%</td>
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<tr>
<td>Practical classes:</td>
<td>15h</td>
<td>12.00%</td>
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<tr>
<td>Laboratory classes:</td>
<td>17h 30m</td>
<td>14.00%</td>
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<td>Guided activities:</td>
<td>5h</td>
<td>4.00%</td>
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<tr>
<td>Self study:</td>
<td>80h</td>
<td>64.00%</td>
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### Content

<table>
<thead>
<tr>
<th>Review of basic concepts</th>
<th>Learning time: 9h 36m</th>
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<tbody>
<tr>
<td>Description:</td>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>Review: stress and body forces; Pascal's law; Archimedes' principle.</td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td>Applications: hydraulic force transmission; pressure measurement.</td>
<td>Self study: 5h 36m</td>
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<tr>
<td>Stratified fluids. Pressure on solid surfaces and immersed bodies</td>
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<tr>
<td>Exercises: mathematical notation (tensors, summation conventions); differential operators and properties; integral theorems.</td>
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<tr>
<td>Hands-on tensor, compact formulation and standard mathematical manipulations</td>
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<thead>
<tr>
<th>Fluid properties</th>
<th>Learning time: 4h 48m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Practical classes: 1h</td>
</tr>
<tr>
<td>Description of physical and thermodynamic properties of a fluid</td>
<td>Laboratory classes: 1h</td>
</tr>
<tr>
<td>Dimensions and units of measurement</td>
<td>Self study: 2h 48m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Governing equations</th>
<th>Learning time: 9h 36m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Theory classes: 2h</td>
</tr>
<tr>
<td>Lagrangian and Eulerian description of motion. Material and time derivative. Reynolds' theorem.</td>
<td>Practical classes: 1h</td>
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<tr>
<td>Deduction of the conservation equations (mass, momentum and energy).</td>
<td>Laboratory classes: 1h</td>
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<tr>
<td>Streamlines, streak lines, particle paths. Vorticity fields</td>
<td>Self study: 5h 36m</td>
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<tr>
<td>Fluid constitutive equations. Newtonian and non-Newtonian fluids</td>
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## Dimensional analysis

**Description:**

**Learning time:** 4h 48m  
Laboratory classes: 2h  
Self study: 2h 48m

## Inviscid flow: Bernoulli's equation

**Description:**

**Learning time:** 4h 48m  
Practical classes: 1h  
Laboratory classes: 1h  
Self study: 2h 48m

## Irrotational flow

**Description:**

**Learning time:** 4h 48m  
Practical classes: 1h  
Laboratory classes: 1h  
Self study: 2h 48m

## Test

**Description:**
Final exam

**Learning time:** 9h 36m  
Laboratory classes: 4h  
Self study: 5h 36m
# Compressible flow

**Description:**
- Small disturbances: speed of sound.
- Shock waves: Rankine-Hugoniot conditions.
- Velocity-area conditions in 1D flows.
- Compressible Navier-Stokes equations.
- Euler equations
- Burgers' equation
- Velocity-area relations in 1D flows
- Boundary conditions for Euler equations

**Learning time:** 14h 23m
- Theory classes: 2h 30m
- Practical classes: 2h
- Laboratory classes: 1h 30m
- Self study: 8h 23m

# Incompressible flow

**Description:**
- Velocity-pressure formulation of the Navier-Stokes equations
- Dimensionless form.
- Stokes equations for viscous flows.
- Exercises: Couette flow, Poiseuille flow, pipe flow...
- Lubrication theory
- Boundary layer theory: hypothesis.
- Derivation of the boundary-layer equations
- Boundary layer on a flat plate. Boundary layer thickness.
- Drag coefficient. Separation. Laminar and turbulent wakes.

**Learning time:** 21h 36m
- Theory classes: 2h
- Practical classes: 6h
- Laboratory classes: 1h
- Self study: 12h 36m

# Introduction to turbulence

**Description:**
- Comparison laminar - turbulent flows. Wall-bounded shear flow.

**Learning time:** 4h 48m
- Laboratory classes: 2h
- Self study: 2h 48m
Flow in porous media

Description:
Flow in porous media
Flow in porous media
Flow in porous media

Learning time: 7h 11m
- Theory classes: 1h
- Practical classes: 1h
- Laboratory classes: 1h
- Self study: 4h 11m

Qualification system

The assessment of this module will be based upon submitted exercises (HW), a mid-term examination (Ex1) and an end of semester examination (Ex2).

The final mark will be computed as:

\[ 0.2 \times \text{HW} + 0.8 \times \text{Ex} \]

being \( \text{Ex} = \max(0.3 \times \text{Ex1} + 0.7 \times \text{Ex2}, \text{Ex2}) \)
Regulations for carrying out activities

The exercises (HW) must be submitted on the announced due date. Work submitted late will normally be awarded half marks. Any late submission must be justified and the lecturer must be informed in advance.

Notes, textbooks, solved problems or any other documents are forbidden during tests.

You may discuss the problems with others, but the worked solutions that you submit are expected to be yours alone.

Unfair practice will be severely punished, in accordance with current academic regulations.

Students must ensure that they do not engage in any form of unfair practice, whereby they take action which may result in them obtaining for themselves or others, an unpermitted advantage.

Unfair practice is defined as any act whereby a person may obtain for himself/herself or for another, an unpermitted advantage. This shall apply whether candidates act alone or in conjunction with another/others. An action or actions shall be deemed to fall within this definition whether occurring during, or in relation to, a formal examination, a piece of coursework, or any form of assessment undertaken in pursuit of the module.

Examples of unfair practice in non-examination conditions are as follows:
* Plagiarism. Plagiarism can be defined as using without acknowledgment another person's work and submitting it for assessment as though it were one's own work, for instance, through copying or unacknowledged paraphrasing;
* Collusion. Collusion can be defined as involving two or more students working together, without prior authorisation from the academic member of staff concerned (e.g. Programme leader, lecturer etc) to produce the same or similar piece of work and then attempting to present this work entirely as their own. Collusion may also involve one student submitting the work of another with the knowledge of the originator.
* Commissioning of work produced by another;
* Falsification of the results of laboratory, field-work or other forms of data collection and analysis.

Bibliography

Basic: