250957 - ELEFINFLUI - Finite Elements in Fluids

**Coordinating unit:** 250 - ETSECCPB - Barcelona School of Civil Engineering  
**Teaching unit:** 751 - DECA - Department of Civil and Environmental Engineering  
**Academic year:** 2015  
**Degree:**  
- MASTER'S DEGREE IN NUMERICAL METHODS IN ENGINEERING (Syllabus 2012). (Teaching unit Compulsory)  
- ERASMUS MUNDUS MASTER'S DEGREE IN COMPUTATIONAL MECHANICS (Syllabus 2013). (Teaching unit Optional)  
- MASTER'S DEGREE IN CIVIL ENGINEERING (RESEARCH TRACK) (Syllabus 2009). (Teaching unit Optional)  
**ECTS credits:** 5  
**Teaching languages:** English

### Teaching staff

**Coordinator:** ANTONIO HUERTA CEREZUELA  
**Others:** RAMON CODINA ROVIRA, MARCO DISCACCIATI, ANTONIO HUERTA CEREZUELA, ESTHER SALA LARDIES

### 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.
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**Teaching methodology**

The course consists of 0.6 hours per week of classroom activity (large size group) and 1.2 hours weekly with half the students (medium size group).

The 0.6 hours in the large size groups are devoted to theoretical lectures, in which the teacher presents the basic concepts and topics of the subject, shows examples and solves exercises.

The 1.2 hours in the medium size groups is devoted to solving practical problems with greater interaction with the students. The objective of these practical exercises is to consolidate the general and specific learning objectives.

The rest of weekly hours devoted to laboratory practice.

Support material in the form of a detailed teaching plan is provided using the virtual campus ATENEA: content, program of learning and assessment activities conducted and literature.

**Learning objectives of the subject**

This course covers the essential theoretical aspects as well as their practical uses, specially for specific techniques for the Euler and Navier-Stokes equations.

* To learn the theoretical and practical fundamentals of the finite elements method applied to the dynamics of fluids to identify the basic theoretical aspects and their inherent computational aspects. * To learn the fundamentals of the numerical approximations in fluid dynamics: The equations, the spatial and temporal discretisations and the most relevant mathematical aspects, such as the stabilisation of convection and incompressibility condition; understanding of the most important aspects of spatial and temporal discretisation as well as identifying the correct boundary conditions and the most suitable method for the solution of different fluid dynamics problems. * The students will develop practical skills to work with tensors and formulate and develop the analysis of diverse problems of fluids in engineering.

- Conservation Equations.
- Stabilisation of the stationary convection equation
- Temporal integration of the transient transport equation.
- Compressible flow.
- Transient convection diffusion problems
- Incompressible Viscous flow.
- Modeling of turbulence.

Learning resources:


Upon completion of the course, students will be able to:
- Understand the fundamentals of finite elements method applied to fluid mechanics problems.
- Discretize fluid flow problems, both in time and space, using the correct boundary conditions and stabilization techniques for convection and incompressibility.
- Use a programming language to implement the discretization techniques, visualizing the results and understanding the methods' behavior.

In particular, students will be able to to demonstrate:
- A knowledge and understanding of the fundamentals of the behavior and numerical approximation of the fluid dynamics equations; spatial and temporal discretizations and relevant mathematical aspects; stabilization of convection and incompressibility.
- An ability to understand and identify the key issues relevant to discretization both in space and time; set up appropriate
initial and boundary conditions; identify the proper methods for the corresponding problem
- An ability to interpret numerical models and to understand the applicability and limitations of different techniques
- An ability to implement and use computer programs to solve fluid dynamics problems; use a programming language to develop computer codes;
- An ability to study independently; use library resources; submit the projects in time; produce project reports and present them.

Study load

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

<table>
<thead>
<tr>
<th><strong>Review of basic concepts</strong></th>
<th><strong>Learning time:</strong> 7h 11m</th>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 1h</td>
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<tr>
<td></td>
<td>Practical classes: 2h</td>
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<td>Self study : 4h 11m</td>
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**Description:**
- Description of the equations of flow motion

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<tr>
<th><strong>Steady transport</strong></th>
<th><strong>Learning time:</strong> 19h 12m</th>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 1h</td>
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<tr>
<td></td>
<td>Practical classes: 3h</td>
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<tr>
<td></td>
<td>Laboratory classes: 4h</td>
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<td>Self study : 11h 12m</td>
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**Description:**
- Analysis of the 1D convection-diffusion equation. Effect of Péclet number and need of stabilization
- 1D convection-diffusion equation with constant coefficients: optimal stabilization parameter.
- Consistent stabilized formulations.

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<tr>
<th><strong>Unsteady convective transport</strong></th>
<th><strong>Learning time:</strong> 19h 12m</th>
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<tbody>
<tr>
<td></td>
<td>Theory classes: 1h</td>
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<td>Practical classes: 3h</td>
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<td>Laboratory classes: 4h</td>
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<td>Self study : 11h 12m</td>
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**Description:**
- Classical time and space discretization techniques: theta-methods and Galerkin discretization.
- Higher-order time integration schemes.
- Discretization using least-squares approximation.
- Stability and accuracy (Courant number).
- Solution of 1D and 2D flows to understand stability and accuracy properties. Influence of Courant number.
### Test

**Description:**
- Mid-term exam
- Final exam

**Learning time:** 9h 36m
- Laboratory classes: 4h
- Self study: 5h 36m

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### Unsteady convection-diffusion

**Description:**
- Fractional step methods.
- High order time-stepping schemes (Padé schemes).
- Discretization using high order time integration schemes. Stabilized formulations.
- Solution of 1D and 2D flows to understand the influence of Courant and Péclet numbers.

**Learning time:** 12h
- Theory classes: 1h
- Practical classes: 2h
- Laboratory classes: 2h
- Self study: 7h

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### Compressible flow

**Description:**
- Basic properties of Euler equations. Boundary conditions.
- Nonlinear hyperbolic scalar equations: weak solutions. Time and space discretization
- Solution of 1D Burgers' equation

**Learning time:** 10h 48m
- Theory classes: 1h
- Practical classes: 2h
- Laboratory classes: 1h 30m
- Self study: 6h 18m
The mark of the course is obtained from the ratings of continuous assessment and their corresponding laboratories and/or classroom computers.

Continuous assessment consist in several activities, both individually and in group, of additive and training characteristics, carried out during the year (both in and out of the classroom).

The teachings of the laboratory grade is the average in such activities.

The evaluation tests consist of a part with questions about concepts associated with the learning objectives of the course with regard to knowledge or understanding, and a part with a set of application exercises.

The course assignments must be submitted on the announced due date. Otherwise a failed mark will be considered. These assignments will involve coding some of the presented methods.

The work that you hand in for marking must be the result of your own efforts. You may discuss the problems with others, but the worked solutions that are submitted are expected to be yours alone. Academic dishonesty will be severely punished, in accordance with current academic regulations.