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: 2019
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)
ECTS credits: 5  Teaching languages: English

Teaching staff
Coordinator: MATTEO GIACOMINI
Others: MATTEO GIACOMINI, ANTONIO HUERTA CEREZUELA, 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.
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.

Learning objectives of the subject

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

* 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.
* Advanced subjects

Learning resources:


This course covers the essential theoretical and practical aspects of the numerical approximation of partial differential equations modeling flow problems, specifically focusing on Euler and Navier-Stokes equations.

Learning objectives: be able to understand the fundamentals of mathematical modeling the motion of fluids, construct numerical algorithms to simulate convection-diffusion-reaction phenomena, understand the numerical difficulties and basic methods to approximate incompressible flows (Stokes and Navier-Stokes equations) and purely convective inviscid flows (Euler equations). More specifically:
- describe, predict and formulate techniques for steady linear scalar convection-diffusion-reaction problems,
- understand stabilization techniques for convection-dominated flows,
- formulate techniques for inviscid flows,
- understand the major difficulties in handling hyperbolic equations and the concept of well-posed Euler problem,
- describe, predict and formulate techniques for incompressible flows,
understand the major difficulties in solving Stokes and Navier-Stokes equations.

Teaching material
Class notes

**Study load**

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

<table>
<thead>
<tr>
<th>Review of basic concepts</th>
<th>Learning time: 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 flow motion equations
- Weak form Discretization
- Elementary matrices and assembly
- Numerical integration
- Reference element

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<thead>
<tr>
<th>Steady transport problems</th>
<th>Learning time: 14h 23m</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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<tr>
<td></td>
<td>Laboratory classes: 3h</td>
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<td>Self study: 8h 23m</td>
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**Description:**
- Analysis of the convection-diffusion equation 1D. Effect of the Péclet number and need for stabilization
- 1D convection-diffusion equation with constant coefficients: optimal stabilization parameter. Consistent stabilized formulations.

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<tr>
<th>Unsteady transport problems</th>
<th>Learning time: 14h 23m</th>
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<tr>
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<td>Theory classes: 1h</td>
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<tr>
<td></td>
<td>Practical classes: 2h</td>
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<td></td>
<td>Laboratory classes: 3h</td>
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<tr>
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<td>Self study: 8h 23m</td>
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**Description:**
- Classical techniques of temporal and space discretization: theta-methods and Galerkin discretization
- Higher-order time integration schemes.
- Discretization using least-squares approximation.
- Stability and accuracy (Courant number).
- Solving problems 1D and 2D to understand the properties of stability and precision. Influence of Couran’s number.
### Compressible flow problems

**Description:**

**Learning time:** 16h 48m  
Theory classes: 1h 30m  
Practical classes: 3h  
Laboratory classes: 2h 30m  
Self study: 9h 48m

### Evaluation

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

### Viscous incompressible flow problems

**Description:**

**Learning time:** 21h 36m  
Theory classes: 2h  
Practical classes: 4h  
Laboratory classes: 3h  
Self study: 12h 36m

### Discontinuous Galerkin

**Description:**
Basic concepts on modern discontinuous Galerkin methods. Formulation and advantages of the hybridizable discontinuous Galerkin for flow problems. Implementation details on HDG.

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

The mark of the course is obtained from the grades of continuous assessment during interactive computer laboratories (10%), mid-term (10%) and final (30%) written exams and one project (50%) to be developed in small groups throughout the duration of the course.

Continuous assessment consist of several activities, both individual and in group, of incremental training, carried out during the year, both in and out of the classroom. The mark of the computer lab is obtained as the average of such activities.

The evaluation tests (mid-term and final) consist of theoretical questions and practical exercises, respectively to explain and apply the concepts related to the learning objectives of the course.

The project consists of a unique work, developed by a small group of students, focusing on the implementation of state-of-the-art numerical methods for flow problems. The mark of the project is obtained as an average of a report and a final discussion.

Regulations for carrying out activities

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.

The written exams (mid-term and final) will be closed-book.

The goals of the project, the related tasks and the members of the group working on it must be arranged with the reference professor at the beginning of the course.

Bibliography

Basic: