295104 - 295II014 - Systems Modeling

Coordinating unit: 295 - EEBE - Barcelona East School of Engineering
Teaching unit: 729 - MF - Department of Fluid Mechanics
Academic year: 2019
Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Teaching unit Compulsory) MASTER'S DEGREE IN MATERIALS SCIENCE AND ADVANCED MATERIALS ENGINEERING (Syllabus 2019). (Teaching unit Optional)
ECTS credits: 6 Teaching languages: English

Teaching staff
Coordinator: RICARDO JAVIER PRINCIPE RUBIO
Others: Primer quadrimestre:
RICARDO JAVIER PRINCIPE RUBIO - T11, T12

Opening hours
Timetable: By appointment.

Prior skills
Calculus. Basic knowledge of partial differential equations.
Fluid mechanics, heat transfer.
Computer usage, notions of programming

Degree competences to which the subject contributes
Specific:
CEMUEII-04. Design and implement modeling techniques to describe the operation of a system. Predict its stability and apply control techniques in different scenarios.

General:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.

Transversal:
05 TEO. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
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Teaching methodology
The hours of driven activities in large groups will be theoretical classes with an expository and participatory approach. The hours of activities directed in small groups will be devoted to the resolution of exercises and the computational simulations systems (in computer rooms) using commercial and open source software. The hours of autonomous learning will be devoted to the study of theory, the solution of problems and computer simulations of systems.

Learning objectives of the subject
- Understand models of physical systems based on partial differential equations, continuum mechanics and constitutive models of fluid mechanics.
- To understand the computational implementations and acquire the skills to modify them to model specific systems
- Identify multi-scale features of physical problems, select appropriate scale separation operators and small scale models.
- Combine physical models though appropriate conditions to model multi-physics problems.
- Estimate the impact of the uncertainty in the model's parameters on the predicted outputs.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group: 34h</th>
<th>22.67%</th>
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<tr>
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<td>Hours medium group: 0h</td>
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<td>Hours small group: 20h</td>
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<td>Guided activities: 0h</td>
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<td>Self study: 96h</td>
<td>64.00%</td>
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## Content

### Introduction to systems modelling

**Learning time:** 16h  
- Theory classes: 4h  
- Self study: 12h

**Description:**
- General concepts about systems modelling. Levels of description, temporal and spatial dependency. Strategies for multiphysics and multiscale problems: resolving or modelling small scale features.  
- Review of continuum mechanics: continuum hypothesis, kinematics (lagrangian and eulerian description), dynamics (Reynolds transport theorem).

**Specific objectives:**
- Understand different levels of descriptions of physical systems and strategies for their modeling.  
- Review general aspects of partial differential equations.  
- Review of continuum mechanics basis.

### Transport problems

**Learning time:** 34h  
- Theory classes: 10h  
- Laboratory classes: 6h  
- Self study: 18h

**Description:**

**Related activities:**
- A1- Numerical solution of ordinary differential equations  
- A2- Numerical solution of parabolic partial differential equations  
- A3- Numerical solution of hyperbolic partial differential equations

**Specific objectives:**
- Recognize different types of transport problems, their physical properties and their computational modelling.  
- Understand temporal integration methods for parabolic and hyperbolic problems  
- Recognize singular perturbation problems
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### Fluid mechanics problems

**Learning time:** 62h  
Theory classes: 10h  
Laboratory classes: 10h  
Self study: 42h

### Description:
- Multiphysics problems: transmission conditions (continuity of variables and fluxes obtained from the weak formulation). Application to fluid-structure interaction and thermally coupled flows.

### Related activities:
- A4. Numerical solution of the Stokes and Navier-Stokes equations (flow past a cylinder, airfoil, driven cavity, etc.)
- A5. Simulation of thermally coupled flows (heat exchangers, refrigeration systems)
- A6. Simulation of fluid-structure interaction (airfoils, blood flows, aneurysms)
- P. Final project

### Specific objectives:
- Understand constitutive modelling and its application to fluid mechanics
- Understand computational implementations of these models and acquire skills to modify them for specific systems.
- Identify coupling mechanisms between different physical phenomena.
## Multiscale modelling

<table>
<thead>
<tr>
<th>Learning time: 38h</th>
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<tr>
<td>Theory classes: 10h</td>
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<tr>
<td>Laboratory classes: 4h</td>
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<tr>
<td>Self study: 24h</td>
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### Description:
- Scale separation by averaging, filtering and projection operators, fine scale modelling by approximation and by homogeneization.
- Turbulence modelling by Reynolds averaging.
- Large eddy simulation: explicit and implicit scale separation.

### Related activities:
A7. Simulation of turbulent flows using RANS models
P. Final project

### Specific objectives:
- Identify multiscale features of physical problems
- Understand the impact of fine scale properties on large scale ones.
- Choose appropriate solution strategies for multiscale problems

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## Qualification system

20% Basic computational lab sessions
20% Applications to systems modelling
20% Final project
40% Final exam

## Regulations for carrying out activities

Individual exam; project and homework in groups of two people.
Bibliography

Basic:


Complementary:

