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
ALFREDO DE JESUS GUARDO ZABAleta - T11, T12

Opening hours
Timetable: By appointment.

Prior skills
Calculus. Basic knowledge of 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 TEQ. 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.
- Understand the concept of weak solutions of partial differential equations, which are key to describe several physical phenomena (e.g. shock waves).
- Understand the concept of regularity of these solutions and how it determines the difficulty of the problem (e.g. the computational cost of numerical simulations).
- Understand the weak formulation of physical laws and the continuity conditions they imply when dealing with multiphysics problems.
- Identify multi-scale features of physical problems, select appropriate scale separation operators and small scale models.

**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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</thead>
<tbody>
<tr>
<td>Hours medium group: 0h</td>
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<td>0.00%</td>
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<tr>
<td>Hours small group: 20h</td>
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<td>13.33%</td>
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<tr>
<td>Guided activities: 0h</td>
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<td>0.00%</td>
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<tr>
<td>Self study: 96h</td>
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<td>64.00%</td>
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## Content

<table>
<thead>
<tr>
<th>Mathematical modeling of systems</th>
<th>Learning time: 20h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 6h</td>
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<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 12h</td>
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</table>

**Description:**
- Introduction to systems modeling
- Description of systems
- Constitutive modeling
- Some simple models

**Related activities:**
- A1 Computational modeling of laminar flows (flow past a cylinder, airfoil, driven cavity, etc.)

**Specific objectives:**
- Understand different levels of descriptions of physical systems and strategies for their modeling.
- Learn continuum mechanics basis, constitutive modeling and possible simplifications.

<table>
<thead>
<tr>
<th>Classical theory of partial differential equations</th>
<th>Learning time: 42h</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 10h</td>
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<tr>
<td></td>
<td>Laboratory classes: 2h</td>
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<tr>
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<td>Self study: 30h</td>
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**Description:**
- Introduction to partial differential equations
- First and second order partial differential equations
- Fundamental solutions and their properties
- Green identities and Green functions

**Related activities:**
- B1 Computational modeling of partial differential equations with regular solutions

**Specific objectives:**
- Learn basic concepts of partial differential equations (order, linearity, type)
- Understand properties of classical solutions (uniqueness, mean value, maximum principle, etc.), including regularity.
General theory of partial differential equations

<table>
<thead>
<tr>
<th>Learning time: 46h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 10h</td>
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<tr>
<td>Laboratory classes: 6h</td>
</tr>
<tr>
<td>Self study : 30h</td>
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</tbody>
</table>

**Description:**
Nonlinear first order partial differential equations, shock waves
Distributions and weak derivatives
Functional spaces and weak formulation of partial differential equations
Numerical methods for partial differential equations

**Related activities:**
B2 Computational modeling of partial differential equations with non-regular (weak) solutions
A2 Computational modeling of compressible flows (shock waves)

**Specific objectives:**
Understand the need for generalized solutions of partial differential equations
Learn the basis of weak derivatives, functional spaces and weak formulations
Understand the impact of regularity on the computational cost of numerical methods

Multiphysics and multiscale modeling

<table>
<thead>
<tr>
<th>Learning time: 42h</th>
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</thead>
<tbody>
<tr>
<td>Theory classes: 8h</td>
</tr>
<tr>
<td>Laboratory classes: 10h</td>
</tr>
<tr>
<td>Self study : 24h</td>
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</tbody>
</table>

**Description:**
Transmission conditions in continuum mechanics.
Classical homogenization theory
Scale separation for nonlinear problems and small scale modeling

**Related activities:**
A3 Computational modeling of fluid-structure interaction (airfoils, blood flows, aneurysms)
B3 Computational modeling of partial differential equations with multiscale features
A4 Computational modeling of turbulent flows

**Specific objectives:**
- Understand continuity conditions implied by the weak formulation of physical laws
- Identify multiscale features of physical problems and learn the basics of scale separation and small scale modeling
- Choose appropriate solution strategies for multiscale problems
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Qualification system

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

Regulations for carrying out activities

Individual exam; homeworks in groups of two people.

Bibliography

Basic:


Complementary: