Degree competences to which the subject contributes

Generical:
CGMUEQ-01. Ability to apply the scientific method and the principles of engineering and economics, to formulate and solve complex problems in processes, equipment, facilities and services, in which the matter undergoes changes in its composition, state or energy content, characteristic of the chemical industry and other related sectors among which are the pharmaceutical, biotechnological, materials, energy, food or environmental
CGMUEQ-04. To carry out the appropriate research, undertake the design and manage the development of engineering solutions, in new or little known environments, relating creativity, originality, innovation and technology transfer
CGMUEQ-05. Know how to establish mathematical models and develop them through appropriate information technology, as a scientific and technological base for the design of new products, processes, systems and services, and for the optimization of others already developed

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.
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.

Teaching methodology
- Regular classes
- Hands-on workshops
- Project based learning
- Seminars

Learning objectives of the subject
After this course the students should be able to do CFD analysis correctly but not to write their own CFD code. They
should also be able to understand the strengths and weaknesses of CFD simulations, and apply it to solve advanced
problems involving turbulence modelling, mixing, reaction/combustion and multiphase flows.

<table>
<thead>
<tr>
<th>Study load</th>
<th>Hours large group:</th>
<th>28h</th>
<th>18.67%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total learning time:</td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Hours small group:</td>
<td>14h</td>
<td>9.33%</td>
</tr>
<tr>
<td></td>
<td>Guided activities:</td>
<td>6h</td>
<td>4.00%</td>
</tr>
<tr>
<td></td>
<td>Self study:</td>
<td>102h</td>
<td>68.00%</td>
</tr>
</tbody>
</table>
1- GENERAL INTRODUCTION TO CFD MODELLING

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Modelling in engineering</td>
</tr>
<tr>
<td>• CFD simulations</td>
</tr>
<tr>
<td>• Applications in engineering</td>
</tr>
<tr>
<td>• Types of flow</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>To explain the input needed to solve CFD problems (CAD geometry, computational mesh, material properties, boundary conditions...), to discuss briefly the difficulty and accuracy of CFD simulations for various applications</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning time: 5h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 1h 30m</td>
</tr>
<tr>
<td>Laboratory classes: 0h</td>
</tr>
<tr>
<td>Self study : 4h</td>
</tr>
</tbody>
</table>

2- CFD SOFTWARES

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• General purpose CFD programs available</td>
</tr>
<tr>
<td>• FLUENT</td>
</tr>
<tr>
<td>• FDS</td>
</tr>
<tr>
<td>• OPENFOAM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Related activities:</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUENT, FDS and OpenFOAM tutorials to do at home.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific objectives:</th>
</tr>
</thead>
<tbody>
<tr>
<td>To introduce the most used commercial CFD programs available, to provide a general view of the three tools that will be used during the course: Fluent, FDS and OpenFOAM.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning time: 9h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 1h 30m</td>
</tr>
<tr>
<td>Laboratory classes: 0h</td>
</tr>
<tr>
<td>Self study : 8h</td>
</tr>
</tbody>
</table>
### 3- MODELLING

**Description:**
- Mass, heat and momentum balances
- The equation of continuity
- The equation of motion
- Energy transport
- The balance for species
- Boundary conditions
- Physical properties

**Related activities:**

**Specific objectives:**
To provide an overview of the equations that are the basis of the CFD modelling and the parameters needed to solve them.

**Learning time:** 5h 30m
- Theory classes: 1h 30m
- Laboratory classes: 0h
- Self study: 4h

### 4- NUMERICAL ASPECTS OF CFD TOOLS

**Description:**
- Numerical methods for CFD
- Cell balancing
- The Gauss-Seidel algorithm
- Measures of convergence
- Discretization schemes
- Solving the velocity field
- Unsteady flows
- Meshing

**Related activities:**
- Laboratory session 1: Numerical methods
- Laboratory session 2: The velocity field
- Laboratory session 3: Cell balancing and meshing

**Specific objectives:**
To introduce commonly used numerical methods. To explain the various methods so that the student will be able to choose the appropriate method with which to perform CFD simulations.

**Learning time:** 27h 30m
- Theory classes: 3h
- Laboratory classes: 4h 30m
- Self study: 20h
### 5- TURBULENT FLOW MODELLING

**Learning time:** 47h 30m  
Theory classes: 6h  
Laboratory classes: 7h 30m  
Self study: 34h

**Description:**
- The physics of fluid turbulence  
- Turbulence modelling  
- Near-wall modelling  
- Inlet and outlet boundary conditions

**Related activities:**
- Laboratory session 4: Turbulence modelling  
- Laboratory session 5: Boundary conditions  
- Laboratory session 6: Project - Problem definition  
- Laboratory session 7: Project - Technical data  
- Laboratory session 8: Project - Geometry

**Specific objectives:**
To provide an insight into the physical nature of turbulence and the mathematical framework that is used in numerical simulations of turbulent flows. To explain why turbulence must be modelled and how turbulence can be modelled.

### 6- TURBULENT MIXING, CHEMICAL REACTIONS AND MULTIPHASE FLOW MODELLING

**Learning time:** 47h 30m  
Theory classes: 6h  
Laboratory classes: 7h 30m  
Self study: 34h

**Description:**
- Problem description  
- The nature of turbulent mixing  
- Mixing of a conserved scalar  
- Modelling of chemical reactions  
- Non-PDF models  
- Multiphase flow modelling

**Related activities:**
- Laboratory session 9: Project - Mesh analysis  
- Laboratory session 10: Project - Simulations 1  
- Laboratory session 11: Projects - Simulations 2  
- Laboratory session 12: Project - Results  
- Laboratory session 13: Project - Report

**Specific objectives:**
To give an introduction to problems faced by engineers wanting to use CFD for detailed modelling of turbulent reactive flows and of multiphase flows. To describe the physical processes of turbulent mixing and know why this can have an effect on the outcome of chemical reactions.
7- BEST PRACTICES GUIDELINES

**Description:**
- Application uncertainty
- Numerical uncertainty
- Numerical errors
- Turbulence modelling
- Reactions and multiphase modelling
- Sensitivity analysis
- Verification, validation and calibration

**Related activities:**
To understand the limitations of the CFD modelling, to explain most common sources of errors and to provide best practices guidelines for CFD simulations.

**Learning time:** 7h
- Theory classes: 1h 30m
- Laboratory classes: 1h 30m
- Self study: 4h

**Qualification system**

\[ NF = 0.4 \times NEF + 0.6 \times NP \]

NF: Final grade  
NEF: Final exam grade  
NP: Projects grade

**Regulations for carrying out activities**

The tests can be done with all the material that the student needs.
Bibliography

Basic:


Complementary:


