**220056 - Computational Aerospace Engineering**

**Coordinating unit:** 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering  
**Teaching unit:** 737 - RMEE - Department of Strength of Materials and Structural Engineering  
**Academic year:** 2019  
**Degree:** BACHELOR'S DEGREE IN AEROSPACE TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)  
**ECTS credits:** 4,5  
**Teaching languages:** Spanish

**Teaching staff**

**Coordinator:** Joaquín A. Hernández Ortega  
**Others:** Joaquín A. Hernández Ortega

**Opening hours**

**Timetable:** Announced in class.

**Prior skills**

Students should have a solid knowledge base in ordinary and partial differential equations for modelling engineering problems. Knowledge of theory of structures and basis of fluid mechanics are also required.

**Degree competences to which the subject contributes**

**Specific:**

1. GrETA - An adequate understanding of the following, as applied to engineering: calculation methods for aeronautical design and development; the use of aerodynamic experimentation and the most important parameters in theoretical application; the experimental techniques, equipment and measuring instruments used in the discipline; simulation, design, analysis and interpretation of in-flight experiments and operations; aircraft maintenance and certification systems.

**Teaching methodology**

The teaching methodology is based on three complementary activities: lectures, computer work and assignments. In the lectures, basic concepts and practical exercises are developed. If it were the case, computer algorithms are also formulated.  
Computer work intends, on the one hand, familiarize students with the basic ideas of programming the algorithms proposed in the theory. On the other hand, introduce the student to the use of commercial software as a design tool; including aspects as hypotheses, constraints, element types, error estimation and results analysis.  
The assessments include tests and hands-on computer assignments. Group homework assignments are allowed.

**Learning objectives of the subject**

Learning the fundamentals of the finite element method as a general numerical tool for solving engineering problems governed by ordinary and partial differential equations. Learning the methodology used to obtain weak forms for the governing equations and the finite element discretization. Becoming familiar with the development of finite element code and also with its application using commercial software package.
### Study load

<table>
<thead>
<tr>
<th>Total learning time: 112h 30m</th>
<th>Hours large group:</th>
<th>31h</th>
<th>27.56%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours small group:</td>
<td>14h</td>
<td>12.44%</td>
</tr>
<tr>
<td></td>
<td>Self study:</td>
<td>67h 30m</td>
<td>60.00%</td>
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</tbody>
</table>
### Content

<table>
<thead>
<tr>
<th>Fundamental concepts; Boundary value problem: one-dimensional case</th>
<th>Learning time: 27h 30m</th>
</tr>
</thead>
</table>
| Theory classes: 8h
| Practical classes: 3h |
| Self study: 16h 30m |

**Description:**
- Strong form. System of differential equations. Boundary conditions
- Equivalence between the strong and weak forms. Natural boundary condition
- Galerkin’s approximation method
- Stiffness matrix; system of equations; gauss elimination
- The element point of view; elemental matrix, elemental forces
- Elastic problem 1D and Euler-Bernoulli beam theory

**Related activities:**
Activity 1: theory classes
Activity 2: practical classes
Activity 3: mid-term exam

**Specific objectives:**
Learning of the fundamentals of the FEM

<table>
<thead>
<tr>
<th>General formulation of the Boundary value problem: 2D and 3D cases</th>
<th>Learning time: 30h</th>
</tr>
</thead>
</table>
| Theory classes: 8h
| Practical classes: 4h |
| Self study: 18h |

**Description:**
- Preliminary concepts. Elastic and heat conduction problem
- Heat conduction: strong form, weak form, and equivalence
- Heat conduction: Galerkin formulation, properties of the stiffness matrix
- Heat conduction: Element stiffness matrix and element force vector
- Elastic problem: strong form, weak form and the equivalence
- Elastic problem: Galerkin formulation, properties of the stiffness matrix
- Elastic problem: Element stiffness matrix and element force vector

**Related activities:**
Activity 1: theory classes
Activity 2: practical classes
Activity 3: mid-term exam

**Specific objectives:**
Fundamentals of the FEM applied to 2D and 3D problems
### Isoparametric elements

**Description:**
- Bilinear quadrilateral element
- Linear triangular element
- Trilinear hexahedral element
- Higher order elements; Lagrange polynomials
- Numerical Integration; Gaussian Quadrature
- Shape functions and Derivatives of shape functions

**Related activities:**
- Activity 1: theory classes
- Activity 2: practical classes
- Activity 4: final exam

**Specific objectives:**
- Element technology description

<table>
<thead>
<tr>
<th>Learning time</th>
<th>Theory classes</th>
<th>Practical classes</th>
<th>Self study</th>
</tr>
</thead>
<tbody>
<tr>
<td>25h</td>
<td>7h</td>
<td>3h</td>
<td>15h</td>
</tr>
</tbody>
</table>

### Mixed and penalty methods applied to incompressibility problems

**Description:**
- Limitations of the standard FEM
- Stokes flow formulation
- Mixed and penalty methods
- Strong form, weak form
- Galerkin approximation, discrete system of equations
- Penalty: selective and reduced integration
- Stabilized techniques
- Introduction to fluid-structure interaction

**Related activities:**
- Activity 1: theory classes
- Activity 2: practical classes
- Activity 4: final exam

**Specific objectives:**
- Extension of FEM to incompressibility problems. Fundamentals of fluid-structure interaction

<table>
<thead>
<tr>
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<th>Practical classes</th>
<th>Self study</th>
</tr>
</thead>
<tbody>
<tr>
<td>30h</td>
<td>8h</td>
<td>4h</td>
<td>18h</td>
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Qualification system

\[ NF = 0.3 \times EM + 0.3 \times EF + 0.4 \times I \]

NF: Final mark
EP: Midterm exam
ER: Midterm exam - extra
EM: \( \max (EP, ER) \)
EF: Final exam
I: Report assignments

The remedial exam will consist of a written test (on the day of the final exam) on the contents of the first partial examination. All students can make the test, regardless of their grade. The exam grade of the first part will be the highest of the two, i.e.: \( EM = \max (EP, ER) \).

Regulations for carrying out activities

Both partial and final tests are written exams and should be carried out individually, on the dates fixed by the School. On the other hand, both class assignments and homework could be done in groups (maximum 2 students per group).

Bibliography

Basic:


Complementary:


Others resources:

Computer material
MATLAB

ANSYS