Course guide
220056 - EAC - Computational Aerospace Engineering

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 737 - RMEE - Department of Strength of Materials and Structural Engineering.
Degree: BACHELOR’S DEGREE IN AEROSPACE TECHNOLOGY ENGINEERING (Syllabus 2010). (Compulsory subject).
Academic year: 2022 ECTS Credits: 4.5 Languages: Spanish

LECTURER
Coordinating lecturer: Joaquín A. Hernández Ortega
Others: Joaquín A. Hernández Ortega

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>Type</th>
<th>Hours</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Hours large group</td>
<td>31,0</td>
<td>27.56</td>
</tr>
<tr>
<td>Self study</td>
<td>67,5</td>
<td>60.00</td>
</tr>
<tr>
<td>Hours small group</td>
<td>14,0</td>
<td>12.44</td>
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</tbody>
</table>
## CONTENTS

### Fundamental concepts; Boundary value problem: one-dimensional case

**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

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

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

**Full-or-part-time:** 27h 30m
Theory classes: 8h
Practical classes: 3h
Self study: 16h 30m

### General formulation of the Boundary value problem: 2D and 3D cases

**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

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

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

**Full-or-part-time:** 30h
Theory classes: 8h
Practical classes: 4h
Self study: 18h
### 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

**Specific objectives:**
- Element technology description

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

**Full-or-part-time:** 25h
- Theory classes: 7h
- Practical classes: 3h
- Self study: 15h

### 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

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

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

**Full-or-part-time:** 30h
- Theory classes: 8h
- Practical classes: 4h
- Self study: 18h
GRADING SYSTEM

NF = 0,3 EM + 0,3 EF + 0,4 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, ie: EM = max (EP, ER).

EXAMINATION RULES.

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:

RESOURCES

Computer material:
- MATLAB
- ANSYS