Matemáticas de la Especialidad Construcción (Mathematics for Construction Engineering) Course topics

Degree in Industrial Engineering Technologies (Grado en Ingeniería en Tecnologías Industriales)

Number of ECTS credits: 4.5

- **0. Review of some basic topics.**
  - Vector spaces. Linear mappings.
  - Bilinear mappings. Norms and scalar products.
  - Best approximation and orthogonal projection.

Module 1. Some numerical tools in engineering.

- 1. **Introduction to numerical computing.**
  - Usefulness and objectives of numerical computing. Computer arithmetic. Normalized scientific notation. Rounding errror.
  - Well posed problem. Problem conditioning. Stability and inestability of algorithms.
- **2. Interpolation.**
  - Introduction.
  - 1D polinomial interpolation. Work with other families of functions.
- **3. Numerical differentiation and integration.**
  - Numerical quadrature formulas.
  - Newton-Cotes formulas. Gaussian formulas.
  - Some formulas of numerical differentiation.
- **4. Numerical solution of systems of linear algebraic equations.**
  - Gaussian elimination and LU factorization. Pivoting.
  - Cholesky factorization.
  - Obtention of the inverse and the determinant of matrix.
  - Conditioning of a linear system.

- **5. Numerical solution of non-linear equations and systems.**
  - Existence and unicity of solution: scalar equations versus systems.
  - Local and global convergence of algorithms.
  - Methods for scalar equations: bisection, Newton, secant and regula-falsi methods.
  - Newton method for systems of equations.
  - Least squares solutions.
- **6. Function approximation and data fitting.**
  - Continuous approximation. Continuous linear least squares.
  - Data approximation. Linear and non-linear curve fitting problems.
- **7. Numerical methods for initial value problems in ordinary differential equations.**
  - Explicit and implicit methods.
  - Some schemes: Euler explicit and implicit, Crank-Nicholson. Runge-Kutta methods.
  - Application to some mechanical problems.
  - Numerical stability and stiff problems.

Module 2. The Finite Element Method (FEM) in linear stationary problems.

- **8. The matrix stiffness method in some mechanical problems.**
  - 1D systems of springs or bars.
  - 2D truss systems.
- **9. Weak formulation in stationary problems: application to the axially loaded abar and to heat conduction.**
  - Strong problem for the axial bar. Integration by parts. Weak problem.
  - Strong problem for heat conduction. Green identities. Weak problem.
  - Relationships between the strong and the weak problem.
  - Natural and essential boubdary conditions.
- **10. The Galerkin method.**
  - Motivation and problem setting. Galerking orthogonality principle.
  - Practical problem solving. Associated linear system. Stiffness matrix and force vector.
- **11. Introduction to FEM: piecewise linear functions.**

- FEM basic principles.
- FEM for the axial bar problem: stepwise linear funcctins.

- **12. The local approach to FEM.**

  - Element definition: degrees of freedom, function space and basis functions.
  - 1D and 2D elements.
  - Element assembly. Finite element space. Global degrees of freedom and global base functions.
  - Treatment of essential boundary conditions.
  - Galerking problem and system of equations.
  - Isoparametric technique.
  - Computation of integrals.
  - Assembly of the stiffness matriz and the force vector.
  - Work with the extended system.
  - Postprocessing.