

Matemáticas de la Especialidad Ingeniería Mecánica (Mathematics for Mechanical 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 error.
- 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 boudnary 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 functions.
- **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.
 - Galerkin problem and system of equations.
 - Isoparametric technique.
 - Computation of integrals.
 - Assembly of the stiffness matrix and the force vector.
 - Work with the extended system.
 - Postprocessing.