19904 - NMSAE - Numerical Methods for Systems of Aerospace Engineering

Coordinating unit: 300 - EETAC - Castelldefels School of Telecommunications and Aerospace Engineering

Teaching unit: 748 - FIS - Department of Physics

Academic year: 2018

Degree: MASTER'S DEGREE IN AEROSPACE SCIENCE AND TECHNOLOGY (Syllabus 2015). (Teaching unit Compulsory)
DOCTORAL DEGREE IN AEROSPACE SCIENCE AND TECHNOLOGY (Syllabus 2007). (Teaching unit Optional)

ECTS credits: 5 Teaching languages: English

Teaching staff

Coordinator: See Course InfoWeb

Others: See Course InfoWeb

Prior skills

Linear algebra, calculus, theoretical modelling of engineering and physics problems

Degree competences to which the subject contributes

Basic:

CB6. (ENG) CB6 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación.
CB7. (ENG) CB7 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.
CB9. (ENG) CB9 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades.
CB10. (ENG) CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

Specific:

CE3 MAST. (ENG) CE3: Aplicar los métodos numéricos para ingeniería aeroespacial con especial énfasis en sus aplicaciones, y en especial en la dinámica de fluidos.

Generical:

CG1 MAST. (ENG) CG1: Identificar y conocer las principales actividades de I+D+i en el campo aeroespacial que se llevan a cabo actualmente a nivel internacional en el ámbito académico, la industria y las mayores agencias espaciales.
CG2 MAST. (ENG) CG2: Identificar y aplicar los análisis teóricos, experimentales y numéricos fundamentales de uso actual en ingeniería aeroespacial.
CG4 MAST. (ENG) CG4: Participar en un proyecto de I+D+i del ámbito aeroespacial aportando una visión y conocimientos novedosos asociados con las técnicas de uso más puntero en el campo.

Transversal:

CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.
CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.
CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

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Teaching methodology

Course lectures are presential and attendance is compulsory. Course materials consist of slide presentations and numerical codes/scripts. Sessions are generally structured as a 2h theory exposition in a classroom, followed by a numerical lab session to implement practical examples of the concepts just learnt.
The methodologies involved are:
MD1: Theory sessions
MD2: Interactive sessions
MD3: Lab sessions
MD5: Autonomous work
MD6: Group work
MD7: Tutorials

Learning objectives of the subject

Overview on numerical methods for
1) solution of linear systems of equations
2) solution of nonlinear systems of equations and optimisation
3) solution of partial differential equations

Study load

Total learning time: 125h	Hours large group:	45h	36.00%
	Hours medium group:	0h	0.00%
	Hours small group:	0h	0.00%
	Guided activities:	0h	0.00%
	Self study:	80h	64.00%

Content

Introduction	Learning time: 10h Theory classes: 5h Self study : 5h

Description:
Course introduction and presentation of the computational tools to be throughout the course.

Related activities:
A01: Theory session
A04: Lab session
A09: Self study

Solution of linear systems of equations	Learning time: 37h Theory classes: 12h Guided activities: 25h

Description:

Overview of direct and iterative numerical methods for matrix factorisation and for the solution of linear systems of equations.

- Overview
  - Problem types: solution of linear systems, solution of eigenproblems
  - Numerical methods concepts: Consistency, stability and convergence
- Direct methods for the solution of linear systems of equations
  - Gaussian elimination
  - LU factorisation
  - Cholesky factorisation
  - Pivoting
  - Other methods (QR factorisation, SVD factorisation...)
- Iterative methods for the solution of linear systems of equations
  - Stationary methods
    - General family of first order methods
    - Jacobi
    - Gauss-Seidel
    - Over/under-relaxation methods
  - Non-stationary methods
    - Gradient methods
      - Steepest descent
      - Conjugate gradients
      - Other methods (GMRES, biCGStab...)
  - Preconditioning

Related activities:

A01: Theory sessions
A02: Interactive sessions
A03: Problem resolution
A04: Lab sessions
A05: Discussion sessions
A08: Tutorials
A09: Self study
A10: Home exercises
A11: Home project
A12: Graded home exercices/activities

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Solution of nonlinear systems and optimisation	Learning time: 37h Theory classes: 12h Self study : 25h

Description:
Overview of numerical methods for the solution of nonlinear systems of equations and for the optimisation of objective functions with continuous dependency on the variables.
- Introduction
- Methods for solving nonlinear systems of equations
  - overview of iterative methods
  - direct iteration
  - Picard's method / secant
  - Newton's method
  - Modified Newton's method
  - Quasi Newton methods
  - Convergence criteria
- Optimisation
  - introduction / notation
  - unconstrained optimisation
    - line search
    - gradient methods
      - steepest descent
      - Newton's optimal method
      - Modified Newton's method
      - Conjugate gradients method
      - Trust region techniques
      - Preconditioning
  - constrained optimisation
    - penalty methods
    - Lagrange multipliers
- multiobjective optimisation

Related activities:
A01: Theory sessions
A02: Interactive sessions
A03: Problem resolution
A04: Lab sessions
A05: Discussion sessions
A08: Tutorials
A09: Self study
A10: Home exercises
A11: Home project
A12: Graded home exercices/activities

Solution of partial differential equations	Learning time: 41h Theory classes: 16h Self study : 25h

Description:
Overview of space and time discretisation schemes, and introduction to the finite element method.
- Introduction
  - Space and time discretisation methods
  - Advantages and disadvantages
  - Application examples
- The finite element method
  - Introduction
  - Weak formulation
  - Space discretisation / polynomial interpolation
  - Treatment of boundary conditions
  - Projection / quadratures
  - Element discretisation / element types
  - System assembly
- Time-dependent problems
  - space semi-discretisation
  - modal analysis
  - time integration
    - overview of time-integration methods
    - family of first order methods
      - Forward Euler, backward Euler and Crank-Nicholson
      - stability and convergence
    - Methods for wave-equations (Newmark)
- Advection-diffusion problems
  - Numerical dissipation
  - stabilisation techniques

Related activities:
A01: Theory sessions
A02: Interactive sessions
A03: Problem resolution
A04: Lab sessions
A05: Discussion sessions
A08: Tutorials
A09: Self study
A10: Home exercises
A11: Home project
A12: Graded home exercices/activities

Qualification system

Exams (50%)
Assignments:
lab work (25%)
home assignment (25%)

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Regulations for carrying out activities

Open book exam

Bibliography

Basic:

Trefethen, Lloyd N; Bau, David. Numerical linear algebra. Philadelphia: SIAM, 1997. ISBN 9780898713619.

Zienkiewicz, O. C; Taylor, Richard Lawrence; Zhu, J. Z. The Finite element method : its basis and fundamentals. 6th ed. Amsterdam [etc.]: Elsevier Butterworth-Heinemann, 2005. ISBN 0750663200.

Quarteroni, Alfio; Saleri, Fausto; Sacco, Riccardo. Numerical mathematics. 2nd ed. New York ; Barcelona [etc.]: Springer, cop. 2007. ISBN 9783540346586.

Quarteroni, Alfio; Saleri, Fausto; Gervasio, Paola. Scientific computing with MATLAB and Octave. 4th ed. Heidelberg [etc.]: Springer, 2014. ISBN 9783642453663.