Course guide
300285 - CE - Computational Engineering

Last modified: 09/06/2023

Unit in charge: Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN AEROSPACE SCIENCE AND TECHNOLOGY (Syllabus 2021). (Optional subject).

Academic year: 2023 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Juan Pedro Mellado

Others:

PRIOR SKILLS

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

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE1 MAST21. Apply the scientific method to the study of the particular phenomenology of the aerospace environment.

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.

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.

Basic:
CB7. Students will be able to apply the acquired knowledge and their ability to solve problems in new or little explored environments in broader (or multidisciplinary) contexts related to their study area.

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

The course is a hands-on introduction to the numerical solution of linear and nonlinear systems, optimization, and ordinary and partial differential equations. The emphasis is on understanding fundamental aspects of numerical methods and the challenges associated with their implementation and validation. After the course, the students are able to find the methods in standard libraries that are more suitable for a particular problem, and they can assess the trade-offs between accuracy and cost. As software, we use python.

STUDY LOAD

Type	Hours	Percentage
Self study	80,0	64.00
Hours large group	45,0	36.00

Total learning time: 125 h

CONTENTS

Introduction.

Description:
- Computational engineering.
- Python3. Optionally, Spyder3 as programming environment.

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

Full-or-part-time: 15h
Theory classes: 4h
Self study : 11h

Linear systems of equations.

Description:
- Direct methods. Operation count. Gaussian elimination, LU factorization, Cholesky factorization. Pivoting. Sparsity and fill-in.
- Iterative methods. Consistency, Stability and Convergence. Stationary methods (Jacobi, Gauss-Seidel, over-relaxation methods) and non-stationary methods (steepest descent, conjugate gradient). 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 exercises/activities

Full-or-part-time: 22h
Theory classes: 8h
Self study : 14h

Nonlinear systems and optimisation.

Description:
- Non-linear systems. Review of iterative methods, direct method, Newton’s method and its variants. Convergence criteria.
- Optimization. Unconstrained optimization, line-search methods, gradient methods. Trust-region 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 exercises/activities

Full-or-part-time: 22h
Theory classes: 8h
Self study : 14h

Ordinary differential equations.

Description:
- Finite difference approximations. Taylor tables. Error analysis. Boundary value problems.
- Time-marching schemes. Explicit and implicit schemes. Error and stability analysis. Initial value problems.

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 exercises/activities

Full-or-part-time: 22h
Theory classes: 8h
Self study : 14h

Partial differential equations.

Description:
- Finite difference methods. Semi-discrete approach (method of lines). Error and stability analysis: Advection-diffusion equations (CFL number and diffusion number).
- Multidimensional problems. Operator splitting.
- Introduction to finite volume methods. Interpolation problem.
- Introduction to finite element methods. Weak formulation. Element discretization. System assembly.

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 exercises/activities

Full-or-part-time: 44h
Theory classes: 16h
Self study : 28h

GRADING SYSTEM

The evaluation is based on take-home assignments, where the students have to write python codes to solve specific problems with the algorithms discussed in class.

5 take-home assignments (100% of the final grade, each 20%).

In case of failing, the grade will be based on one additional written in-class exam on the date fixed in the calendar of final exams. The grade obtained in the additional written in-class exam will range between 0 and 10 and will replace that of the course based on the take-home assignments.

EXAMINATION RULES.

Open book exam

BIBLIOGRAPHY

Basic:

- Trefethen, Lloyd N; Bau, David. Numerical linear algebra. Philadelphia: SIAM, 1997. ISBN 9780898713619.
- Quarteroni, Alfio; Saleri, Fausto; Gervasio, Paola. Scientific computing with MATLAB and Octave [on line]. 4th ed. Heidelberg [etc.]: Springer, 2014 [Consultation: 18/01/2021]. Available on: http://dx.doi.org/10.1007/978-3-642-12430-3. ISBN 9783642453663.
- Zienkiewicz, O. C; Taylor, Richard Lawrence; Zhu, J. Z. The Finite element method : its basis and fundamentals [on line]. 6th ed. Amsterdam [etc.]: Elsevier Butterworth-Heinemann, 2005 [Consultation: 15/04/2020]. Available on: https://www.sciencedirect.com/science/book/9780750664318. ISBN 0750663200.
- Quarteroni, Alfio; Saleri, Fausto; Sacco, Riccardo. Numerical mathematics [on line]. 2nd ed. New York ; Barcelona [etc.]: Springer, cop. 2007 [Consultation: 15/04/2020]. Available on: https://link.springer.com/book/10.1007/b98885. ISBN 9783540346586.