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230464 - MNC2 - Numerical and Computational Methods 2

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2019
Degree: BACHELOR'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2011). (Teaching unit Compulsory)
ECTS credits: 6 Teaching languages: English

Teaching staff

Coordinator: ALVARO MESEGUER SERRANO

Others: FRANCISCO MARQUES TRUYOL - ALVARO MESEGUER SERRANO

Opening hours

Timetable: A. Meseguer: wednesdy (10:00 - 13:00 and by appointment)
F. Mellibovsky (by appointment)

Prior skills

C1) Mathematics: knowledge of linear algebra, differential calculus / integral in Rn, ordinary differential equations.

C2) Programming: Basic knowledge of Matlab / Octave and programming tools with high performance scientific calculators (HP48, 49 50 or similar).

C3) Numerical methods: polynomial interpolation, solution methods of nonlinear approaches (1 variable), derivation / integration number (1 variable)

Requirements

R1) Numerical and Computational Methods 1
Linear Algebra
Calculus 1/2
Mathematical Methods 1/2

R2) Knowledge of Analytical Mechanics / Fluids

Degree competences to which the subject contributes

Specific:

3. Ability to select numerical and optimization methods suitable for solving physical and engineering problems. Ability to apply the knowledge of numerical algorithms and optimization.
2. Ability to solve problems in physics and engineering using fundamental numerical methods: experimental data processing, interpolation, roots of nonlinear equations, numerical linear algebra and optimization, quadrature and integration of differential equations, properly weighting their different aspects (accuracy, stability and efficiency or cost).
1. Understanding and mastery of computer programming, use of operative systems and computational tools (scientific software). Skills to implement numerical algorithms in languages of low (C, F90) and high (Matlab) level.

Generical:

5. ABILITY TO IDENTIFY, FORMULATE, AND SOLVE PHYSICAL ENGINEERING PROBLEMS. Planning and solving physical engineering problems with initiative, making decisions and with creativity. Developing methods of analysis

and problem solving in a systematic and creative way.

Transversal:

2. EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 2. Designing and executing a good strategy for advanced searches using specialized information resources, once the various parts of an academic document have been identified and bibliographical references provided. Choosing suitable information based on its relevance and quality.
4. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.
1. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.
3. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

Teaching methodology

Lectures (2.6 ECTS): presentation of theoretical concepts and their applications in problem solving. Practicals: resolution of specific problems with computer (Individual / team). Tutorials.

Learning objectives of the subject

To be able of numerically formulating problems arising in physics and engineering and implementing robust and accurate algorithms for their solution.

Study load

Total learning time: 150h	Hours large group:	39h	26.00%
	Hours small group:	26h	17.33%
	Self study:	85h	56.67%

Content

1. Numerical Linear Algebra and Systems of Nonlinear Equation	Learning time: 73h Theory classes: 19h Laboratory classes: 11h Guided activities: 1h Self study : 42h

Description:
1.1 Direct linear solvers (I): Gauss Elimination (GEM) and LU factorization.
1.2 Direct linear solvers (II): PA=LU factorization and partial pivoting.
1.3 QR factorization (I): Orthogonal matrices, Householder reflectors.
1.4 QR factorization (II): Least squares problem.
1.5 Conditioning: Matrix norms, condition numbers and sensitivity of linear systems.
1.6 Gram-Schmidt orthonormalization: Numerical instability of GS and Reorthogonalized-GS.
1.7 Iterative Krylov Methods (I): Richardson iteration and Krylov subspaces.
1.8 Iterative Krylov Methods (II): GMRES and Arnoldi iteration.
1.9 Systems of Nonlinear Equations (I): Newton's method.
1.10 Systems of Nonlinear Equations (II): Parameter-dependent systems and arc-length continuation.

2. Approximation Theory	Learning time: 41h Theory classes: 10h Laboratory classes: 9h Guided activities: 1h Self study : 21h

Description:
2.1 Least Squares Problem in Functional spaces.
2.2 Generalized Fourier Series.
2.3 Bounded domains (Legendre and Chebychev polynomials).
2.4 Periodic domains (Fourier trigonometric polynomials and DFT).
2.5 Applications (I): Fourier-Chebychev-Legendre diferentiation matrices.
2.6 Applications (II): Computation of boundary value problems.
2.7 Applications (III): Computation of eigenfunctions and spectra of Sturm-Liouville problems.

3. Ordinary Differential Equations (Initial Value Problems)	Learning time: 36h Theory classes: 10h Laboratory classes: 4h Guided activities: 1h Self study : 21h

Description:

3.1 Introduction: Cauchy-Picard Theorem, existence and uniqueness of solutions to IVP.
3.2 Linear multistep formulas (I): Characteristic polynomials, local truncation error and order of accuracy. Adams formulas and Curtiss-Hirschfelder BDF methods.
3.3 Linear multistep formulas (II): Stability and convergence of LMSF. Dahlquist's First Stability barrier.
3.4 Linear multistep formulas (III): A-stability, Dahlquist's Second Stability barrier. Explicit Runge-Kutta methods.

Qualification system

1. Mid-semester exam (PE) : weight 30% of the total.

2. Final Exam (FE) of all course content: weight 50% - 80% of the total mark, depending on maximization criteria.

3. Evaluation computing laboratory practicals: weight 20% of the total.

COURSE GRADE = max {0.8 x EF, EF + 0.5 x 0:30 x EP} + 0.2 x P

Bibliography

Basic:

Kincaid, D; Cheney, E. W. Numerical analysis: mathematics of scientific computing. 3th ed. Pacific Grove [etc.]: Brooks/Cole, 2002. ISBN 0534389058.

Complementary:

Quarteroni, A.; Saleri, F.; Sacco, R. Numerical mathematics [on line]. 2nd ed. New York ; Barcelona [etc.]: Springer, 2007 [Consultation: 25/09/2018]. Available on: <https://link.springer.com/book/10.1007/b98885>. ISBN 3540346589.

Watkins, D. S. Fundamentals of matrix computations. 3rd ed. Hoboken: Wiley, 2010. ISBN 9780470528334.