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: 2017
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: wednesday (10:00 - 13:00 and by appointment)
F. Mellibovsky (by appointment)

Prior skills

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 INFORMATION 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


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

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group:</th>
<th>39h</th>
<th>26.00%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Hours small group:</td>
<td>26h</td>
<td>17.33%</td>
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<tr>
<td></td>
<td>Self study:</td>
<td>85h</td>
<td>56.67%</td>
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## 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 differentiation 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.

**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.

   \[ \text{COURSE GRADE} = \max \{0.8 \times \text{EF}, \text{EF} + 0.5 \times 0.30 \times \text{EP}\} + 0.2 \times \text{P} \]

**Bibliography**

**Basic:**

**Complementary:**