250337 - MODNUMER - Numerical Modelling

Coordinating unit: 250 - ETSECCPB - Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering
Academic year: 2017
Degree: BACHELOR'S DEGREE IN GEOLOGICAL ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 4,5  Teaching languages: Catalan, Spanish, English

Teaching staff
Coordinator: ALBERTO GARCIA GONZALEZ
Others: ALBERTO GARCIA GONZALEZ, ABEL GARGALLO PEIRO, JOSE SARRATE RAMOS

Opening hours
Timetable: Office hours will be announced at the beginning of the course.

Degree competences to which the subject contributes

Specific:
4045. Deposit modelling
4056. Knowledge of basic numerical calculus as applied to engineering

Transversal:
588. SUSTAINABILITY AND SOCIAL COMMITMENT - Level 1. Analyzing the world’s situation critically and systematically, while taking an interdisciplinary approach to sustainability and adhering to the principles of sustainable human development. Recognizing the social and environmental implications of a particular professional activity.
592. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 2. Using strategies for preparing and giving oral presentations. Writing texts and documents whose content is coherent, well structured and free of spelling and grammatical errors.
596. 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.
599. EFFECTIVE USE OF INFORMATION RESOURCES - Level 3. Planning and using the information necessary for an academic assignment (a final thesis, for example) based on a critical appraisal of the information resources used.
602. SELF-DIRECTED LEARNING - Level 3. Applying the knowledge gained in completing a task according to its relevance and importance. Deciding how to carry out a task, the amount of time to be devoted to it and the most suitable information sources.
584. 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.
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**Teaching methodology**

The course consists of 3 hours per week of classroom activity (large size group).

The 1.3 hours in the large size groups are devoted to theoretical lectures, in which the teacher presents the basic concepts and topics of the subject, shows examples and solves exercises.

The rest of weekly hours devoted to laboratory practice.

Support material in the form of a detailed teaching plan is provided using the virtual campus ATENEA: content, program of learning and assessment activities conducted and literature.

**Learning objectives of the subject**

Students will learn to formulate and program analytical models and numerical calculation models for design, planning and management; acquire the capacity to interpret results; and learn to apply these models to solve technological problems.

Upon completion of the course, students will be able to: 1. Use numerical analysis software to conduct sensitivity analyses of problems involving the solution of ordinary differential equations; 2. Use a partial differential equation to solve a boundary problem in a continuous medium, obtaining a numerical solution through finite difference (DF) or finite element methods (EF); 3. Use numerical techniques to solve engineering problems; 4. Analyse and solve deposit modelling problems.

Introduction to numerical modelling; Modelling in engineering; Conservation equations; Constitutive equations; Formulation of mathematical problems; Numerical simulation; Numerical solution of partial differential equations; Classification of methods; Difference operators; Convergence, stability and consistency of a difference scheme; Evolution problems: Diffusion, heat transfer, equilibrium; Eigenvalue problems: Introduction to the finite element method; Transport problems: Convection and convection-diffusion equations; Wave problems: Solution of ordinary differential equations; Solution of equations in partial derivatives: Finite differences and finite elements; Deposit modelling

**Study load**

| Total learning time: 112h 30m | Hours large group: 17h 15.11% | Hours medium group: 0h 0.00% | Hours small group: 28h 24.89% |
| Guided activities: 4h 30m 4.00% | Self study: 63h 56.00% |
Ordinary Differential Equations (ODE)

Description:
Introduction to Euler's method.

Local and global error. Order of convergence. Possible improvements.
Propose, implement and compare the different variations of Euler methods. Analyse their properties. Examples.
Introduction to the family of Runge-Kutta methods. RK1, RK2, RK3, RK4.
Application to case studies. Computational cost comparison.
Initial value problem. Examples.
Examples of initial value problems. Introduction and boundary problems. Shooting method.
Computer lab: shooting method

Specific objectives:
Brief introduction to the subject.
Basics on modeling, theory and practical examples.
To know some applications of ODEs.
To understand conceptually what is the discretization of the domain and its relation to the approximation of the derivatives.
To understand the Euler method.
To have basic knowledge of its computer implementation.
Understand the concepts of local and global errors.
To understand the consequences of evaluating numerical derivatives in different ways.
To know the development and properties of Runge-Kutta methods.
To acquire, from practice, an idea of the numerical properties of the different methods.
To know how to convert a higher-order ODE into a system of first order ODEs.
To understand what is an initial value problem and what is a boundary value problem.

To understand how to use the shooting method for boundary value problems.
## Description:
- Computer exercises.
- Examples, implementation and stability.
- Examples, implementation and stability.

## Specific objectives:
- To demonstrate an ability to analyze, represent and interpret various engineering problems that require solving PDEs.
- To demonstrate knowledge and understanding of: identification and classification of second order PDEs, from a mathematical and physical point of view, the meaning of the boundary conditions, the dimensionless form of initial or boundary value problems (in particular “heat”).

- First and second order difference operators,
- To understand and to solve diffusion problems by finite differences explicit in time.
- To understand the concept of stability.
- To acquire basic ideas on the implementation of the FTCS method.
- To understand and to solve diffusion problems by implicit finite differences.
- To acquire basic ideas on the implementation and use of the BTCS method. To know their stability and convergence properties.
- To understand and being able to solve a diffusion problem using finite elements and Crank-Nicolson for the time discretization.
- To acquire basic notions on the implementation and use of the Crank-Nicolson method. To know their properties: stability, convergence, etc..
### Partial Differential Equations - Finite Elements

**Description:**
Continued
Basic syntax. Meshing.
Continued
Boundary conditions. Poisson Problem
FEM exam

**Specific objectives:**
- To know FEM applications in engineering.
- To being able to determine the weak form for elliptic problems with Dirichlet, Neumann or Robin boundary conditions.
- To being able to describe the various numerical aspects of FEM: discretization / approximation, integration, assembly, equation solving, ...
- To know Castem environment and syntax.
- Learn how to use basic meshing tools.
- To solve a parabolic problem using Castem.

<table>
<thead>
<tr>
<th>Learning time: 21h 36m</th>
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<tbody>
<tr>
<td>Theory classes: 4h</td>
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<tr>
<td>Laboratory classes: 5h</td>
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<tr>
<td>Self study: 12h 36m</td>
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</tbody>
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### Optimization

**Description:**
Lab exercises
Simple version of the simplex algorithm.
opt

**Specific objectives:**
- To know, identify, classify and state an optimization problem.
- To solve a linear optimization problem using Matlab.
- To understand the basic ideas on the simplex method.

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<tr>
<th>Learning time: 19h 12m</th>
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<tbody>
<tr>
<td>Theory classes: 5h</td>
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<tr>
<td>Laboratory classes: 3h</td>
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<tr>
<td>Self study: 11h 12m</td>
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Qualification system

The final grade of the course is obtained from the group assessment test (practical projects) and from the individual assessment tests.

During the course students will carry out several practical projects. At its completion the students will work in groups and will apply the acquired knowledge to solve engineering problems.

During the course there will be three individual assessment tests. The exams can consist of a part with questions on concepts associated with learning objectives in terms of subject knowledge and understanding, and a set of application exercises.

The grade for the group assessment test or practical projects (GT) is the average grade for all practical projects.

The grade for individual assessment tests (IT) is the average grade for all the exams.

The final grade for the course (FG) is calculated according to the expression:

\[ FG = GT ^ \left( \frac{1}{4} \right) \times IT ^ \left( \frac{3}{4} \right) \]

Criteria for re-evaluation qualification and eligibility: Students that failed the ordinary evaluation and have regularly attended all evaluation tests will have the opportunity of carrying out a re-evaluation test during the period specified in the academic calendar. Students who have already passed the test or were qualified as non-attending will not be admitted to the re-evaluation test. The maximum mark for the re-evaluation exam will be five over ten (5.0). The non-attendance of a student to the re-evaluation test, in the date specified will not grant access to further re-evaluation tests. Students unable to attend any of the continuous assessment tests due to certifiable force majeure will be ensured extraordinary evaluation periods.

These tests must be authorized by the corresponding Head of Studies, at the request of the professor responsible for the course, and will be carried out within the corresponding academic period.

Regulations for carrying out activities

Failure to perform a laboratory or continuous assessment activity in the scheduled period will result in a mark of zero in that activity.

It will be indispensable to pass the course the presentation of all exercises and practical work. The marks of the assignments are based on the content corresponding to this module, and also on the proper writing, presentation, and how concise is the report.

Bibliography

Basic:


