

250406 - ENGCAMP - Computational Engineering

| | | | |
|--------------------|--|---------------------|---------|
| Coordinating unit: | 250 - ETSECCPB - Barcelona School of Civil Engineering | | |
| Teaching unit: | 751 - DECA - Department of Civil and Environmental Engineering | | |
| Academic year: | 2015 | | |
| Degree: | MASTER'S DEGREE IN CIVIL ENGINEERING (PROFESSIONAL TRACK) (Syllabus 2012). (Teaching unit Compulsory) MASTER'S DEGREE IN CIVIL ENGINEERING (RESEARCH TRACK) (Syllabus 2009). (Teaching unit Optional) | | |
| ECTS credits: | 6 | Teaching languages: | English |

Teaching staff

| | |
|--------------|---|
| Coordinator: | ANTONIO RODRIGUEZ FERRAN |
| Others: | IRENE ARIAS VICENTE, ANTONIO RODRIGUEZ FERRAN, JOSE SARRATE RAMOS |

Opening hours

Timetable: Will be announced at the beginning of the course.

Degree competences to which the subject contributes

Specific:

8200. The ability to apply knowledge of soil and rock mechanics to the study, design, construction and operation of foundations, cuts, fills, tunnels and other constructions over or through land, whatever its nature and state, and whatever the purpose of the work.

8228. Knowledge of and competence in the application of advanced structural design and calculations for structural analysis, based on knowledge and understanding of forces and their application to civil engineering structures. The ability to assess structural integrity.

8230. The ability to plan, dimension, construct and maintain hydraulic works.

8231. The ability to plan, evaluate and regulate the use of surface water and groundwater resources.

8233. Knowledge of and the ability to understand dynamic phenomena of the coastal ocean and atmosphere and respond to problems encountered in port and coastal areas, including the environmental impact of coastal interventions. The ability to analyse and plan maritime works.

8234. Knowledge of transport engineering and planning, transport types and functions, urban transport, management of public transport services, demand, costs, logistics, and financing of transport infrastructure and services.

Teaching methodology

Taught module delivery: fifteen weeks of teaching, coursework and self-study. Apart from the 4 hours per week in the classroom, self-study must last an average of 6 hours per week.

Learning objectives of the subject

Students will learn to design computational models for the mechanics of continuous media and for solving diagnostic problems encountered in engineering.

Upon completion of the course, students will be able to:

250406 - ENGCAMP - Computational Engineering

Develop computational models based on mechanics of continuous media and apply them to different areas of civil engineering, including soil and rock mechanics, structural analysis, hydrology and water resources, ports and coastal systems;

Develop discrete computational models and use them for network design in different areas of civil engineering, in particular transport, logistics, power distribution and infrastructure mapping;

Apply the uncertainty principle to data on the external actions and internal properties of systems;

Apply stochastic computational models and subject the results to statistical processing;

Use the results of computational models as the basis for design, analysis, optimisation and decision-making in civil engineering.

Computational engineering techniques for the modelling and solution of continuous equilibrium and evolution problems;

Application to structural engineering, geotechnical engineering, transport engineering, maritime engineering and environmental engineering; Continuous optimisation techniques (linear programming and nonlinear programming):

Application to optimal design, parameter identification and resource allocation; Discrete optimisation and combinatorial optimisation techniques: Application to network design; Monte Carlo simulation: Application to decision-making in management and planning

Study load

| | | | |
|---------------------------|---------------------|-----------|--------|
| Total learning time: 150h | Theory classes: | 17h 24m | 11.60% |
| | Practical classes: | 8h 24m | 5.60% |
| | Laboratory classes: | 26h 13,2m | 17.48% |
| | Guided activities: | 1h 58,8m | 1.32% |
| | Self study: | 96h | 64.00% |

250406 - ENGCAMP - Computational Engineering

Content

| | |
|--|---|
| <p>1.- Modelling with ODEs</p> | <p>Learning time: 21h 36m</p> <p>Theory classes: 5h Practical classes: 2h Laboratory classes: 2h Self study : 12h 36m</p> |
| <p>Description:</p> <p>Initial value problems in numerical engineering Mètodes simple step (Runge-Kutta) for initial value problems Boundary value problems in engineering The shooting method for boundary value problems Solution of two problems (fields: structural analysis / geotechnics) Adaptive numerical techniques Variable step: step adaptation based on error control The Runge-Kutta-Fehlberg 45 method (RKF45) Solution of a case study (field: structural analysis)</p> <p>Specific objectives:</p> <ul style="list-style-type: none"> To be able to model engineering problems with ODEs To know and to use, with the help of Matlab or Octave, numerical techniques for initial value problems To identify whether an engineering problem is an initial value problem or a boundary value problem To know the strategy to solve boundary value problems, based on iterations (shoots) of an associated initial value problem To model two case studies as boundary value problems: ODEs and boundary conditions To sketch the solution of the boundary value problems with the shooting method To be able to assess and control the quality of the numerical solution To know and to be able to apply the RKF45 method to initial value and boundary value problems To solve a boundary value problem with the RKF45 method (command ode45 in Matlab) To be able to choose the accuracy needed in a computation depending on the output of interest | |

250406 - ENGCAMP - Computational Engineering

| | |
|---|---|
| <p>2.- Modelling with PDEs</p> | <p>Learning time: 43h 12m</p> <p>Theory classes: 8h Practical classes: 4h Laboratory classes: 6h Self study : 25h 12m</p> |
| <p>Description:</p> <p>Solution of two problems (field: hydraulics / soil mechanics) Solution of a case study (field: structural analysis) with the FEM Eigenvalue problems in engineering Wave equation (vibrations, sea waves, sound). Eigenmodes and eigenfrequencies Standard and generalized eigenvalue problems Properties of the symmetric eigenvalue problem Methods of direct vector iteration and inverse vector iteration Solution of two case studies (field: structural dynamics / marine engineering) Diffusion and convection-diffusion problems in engineering Solution of evolution problems with the FEM</p> <p>Solution of a case study (field: environmental engineering) Nonlinear equilibrium problems in engineering Incremental-iterative strategy: the Newton-Raphson method Solution of a case study (field: structural analysis) with the FEM</p> <p>Specific objectives:</p> <ul style="list-style-type: none"> To model two case studies as equilibrium problems: PDEs and boundary conditions To sketch the solution of equilibrium problems with the finite element method (FEM) To know the internal organization of a finite element code To be able to solve equilibrium problems with a finite element code To interpret results, to evaluate and control the quality of outputs of interest To know the most relevant eigenvalue problems in engineering To give a physical interpretation to eigenvectors (modes) and eigenvalues (frequencies) To know numerical techniques to determine the eigenvalues and eigenvectors of interest To be able to determine eigenfrequencies and eigenmodes of interest To understand the basic idea of modal analysis To identify whether a problem is an equilibrium or an evolution problem To know numerical techniques to treat time variation and convection To model a case study as a convection-diffusion problem To sketch its solution with the FEM To identify the different sources of nonlinearity in engineering To know numerical FEM techniques for nonlinear problems To model nonlinearity in a case study To be able to solve nonlinear problems with a finite element code To understand the large difference in complexity between linear and nonlinear problems | |
| <p>Test #1</p> | <p>Learning time: 4h 48m</p> <p>Laboratory classes: 2h Self study : 2h 48m</p> |



250406 - ENGCAMP - Computational Engineering

| | |
|---------|--|
| Test #2 | Learning time: 4h 48m Laboratory classes: 2h Self study : 2h 48m |
| | |

250406 - ENGCAMP - Computational Engineering

| | |
|---|--|
| <h3>3.- Optimization and simulation</h3> | <p>Learning time: 40h 48m</p> <p>Theory classes: 14h Practical classes: 2h Laboratory classes: 1h Self study : 23h 48m</p> |
| <p>Description:</p> <p>Introduction to optimization. Types of problems in engineering</p> <p>Numerical techniques for continuous optimization problems without constraints Models in engineering with unknown parameters Nonlinear least-squares fitting from experimental measures Numerical techniques: Newton, Levenberg-Marquardt Heuristic techniques: genetic algorithms Solution of a case study (field: soil mechanics / structural analysis) Optimization problems in engineering Equality and inequality constraints Optimization with equality constraints: Lagrange multipliers Optimization with inequality constraints: active constraints, barrier functions, penalty functions Linear programming problems in engineering Linear goal function and linear constraints The simplex method Solution of a case study (field: resource allocation) Network problems in engineering Exact and heuristic algorithms in discrete and combinatorial optimization Simulation: Montecarlo method</p> <p>Specific objectives:</p> <p>Identify the different types of engineering problems: direct, optimal design, optimal identification and optimal control. Establish the relationship between unconstrained minimization and the solution of nonlinear systems of equations</p> <p>To discuss whether a model is linear or nonlinear in its parameters To formulate parameter identification as a minimization problem To know how to apply Levenberg-Marquardt method for parameter fitting To know the basic idea of genetic algorithms To model a case study as a problem of parameter identification To solve it with the Levenberg-Marquardt method To know the different types of optimization problems in engineering To understand the role played by the constraints To understand the different numerical treatment of problems with and without constraints To know the basic idea of numerical techniques for constraints To know different types of linear programming problems in engineering To understand the basic rules of the simplex method To model a resource allocation case study as a linear programming problem To solve it with the simplex method To formulate network design problems as discrete /combinatorial optimization problems To know the basic idea of the two types of techniques: exact and approximate Decision making</p> | |

250406 - ENGCAMP - Computational Engineering

| | |
|-------------------|--|
| Test #3 | Learning time: 4h 48m Laboratory classes: 2h Self study : 2h 48m |
| | |
| Course assignment | Learning time: 4h 48m Laboratory classes: 2h Self study : 2h 48m |
| | |

Qualification system

- 1.- The course assignment must be submitted on the announced due date. Otherwise a failed mark will be considered.
- 2.- The tests will cover all the taught material from the beginning of the module.
- 3.- Students have to bring a calculator with no internet connection to the tests. Mobile phones, computers, tablets or any other electronic devices are forbidden during tests.
- 4.- Notes, textbooks, solved problems or any other documents are forbidden during tests.
5. Academic dishonesty will be severely punished, in accordance with current academic regulations.
- 6.- The final mark for the module is obtained from every rated activity according to:

$$\text{Mark} = A^{(1/2)} * TC^{(1/4)} * (E + TD)^{(1/4)}$$

$$\text{If Mark} < 5, \text{Mark} = \max(\text{Mark}, PC^{(3/4)} * TC^{(1/4)})$$

A is the arithmetic mean of the tests: $A = (A1 + A2 + A3)/3$

TC is the arithmetic mean of course assignment: 50% for the poster and its presentation, and 50% for the final report.

The course contains various assignments in class (E) and tutorials in the computer room (TD). Some of them will be submitted at the end of the class for grading. Of these, the best marks (three out of each four) will be used to compute the arithmetic mean of assignments in class and tutorials, E + TD.

PC is the mark of a global assessment.

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.

The Course Assignment is required in order to be marked.

250406 - ENGCAMP - Computational Engineering

Bibliography

Basic:

- Dennis, J.E.; Schnabel, R.B.. Numerical Methods for Unconstrained Optimization and Nonlinear Equations. SIAM, 1996.
- Bathe, K.J.. Finite Element Procedures. Prentice Hall, 1996.
- Deuflhard, P.; Bornemann, F.. Scientific Computing with Ordinary Differential Equations. Springer, 2010.
- Donea, J.; Huerta, A.. Finite Element Methods for Flow Problems. Wiley, 2003.
- Nocedal, J.; Wright, S.J.. Numerical Optimization. 1999.

Complementary:

- Belytschko, T.; Liu, W.K.; Moran, B.. Nonlinear Finite Elements for Continua and Structures. Wiley, 2001.
- Zienkiewicz, O.C.; Taylor, R.L.. The Finite Element Method. Volume 3: Fluid Dynamics. Butterworth-Heinemann, 2000.