UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Course guide
250951 - ELEMFINIT - Finite Element

Last modified: 28/03/2024

Unit in charge: Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN NUMERICAL METHODS IN ENGINEERING (Syllabus 2012). (Compulsory subject).
ERASMUS MUNDUS MASTER'S DEGREE IN COMPUTATIONAL MECHANICS (Syllabus 2013). (Compulsory subject).

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

LECTURER

Coordinating lecturer: PAVEL RYZHAKOV

Others: PEDRO DIEZ MEJIA, PAVEL RYZHAKOV, JOSE FRANCISCO ZARATE ARAIZA

TEACHING METHODOLOGY

The course consists of 4 hours per week of classroom activity .

Part of the hours 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 the hours is devoted to solving practical problems with greater interaction with the students. The objective of these practical exercises is to consolidate the general and specific learning objectives.

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

Although most of the sessions will be given in the language indicated, sessions supported by other occasional guest experts may be held in other languages.

LEARNING OBJECTIVES OF THE SUBJECT

This course is the student's first approach to the basic concepts of the Finite Element Method, including the basic formulation, analysis of the obtained methods, and essential aspects of their implementation. The presentation is carried out using linear problems with practical applications as heat transfer and elasticity, complemented by practical exercises.

* The student will be able to understand and assimilate the foundations of the linear analysis with finite elements, obtain the weak form of the variational formulation and its solution, as well as know the basic structure of a finite elements program. * Comprehend why the method of the finite elements approximates to the solution of the PDE, considering the errors of truncation, consistency, convergence, and stability of the solution of a linear system of equations and the eigenvalue problems. * Manually solve linear problems of mechanics and transfer of heat using FE and simultaneously be able to use properly an FE code to obtain solutions for engineering problems. * The students will also develop the capacity of abstraction and synthesis, understand the structure of vectorial spaces and the concept of linearity. * The students will have to acquire independence in their studies, be able to implement and use computer programs and rationally interpret the results obtained.

Introduction to the finite elements methods
* Errors
* Linear Systems of equations
* Approximation and interpolation
* Numerical Integration
* Discrete Systems and continuous systems. Introduction to the FEM
* Solving with FEM of one-dimensional problems.
* Application to Poisson equation
* More advanced one-dimensional finite Elements
* Application of the FEM to the equation of Poisson in two dimensions
* Application of the FEM to the equation of Poisson in three dimensions
* Matrix Formulation for the solution of Poisson's problem through the FEM
* Obtaining of shape functions for two and three-dimensional class C0 elements
* Two and three-dimensional isoparametric elements
* Two-dimensional elasticity problems
Learning resources:
o Zienkiewicz, O.C.; Morgan, K., Finite elements and approximation, Wiley, 1983
o Hughes, T.J.R., The finite element method, Prentice-Hall,1987
o Henwood, D.J., Bonet, J., Finite elements - A gentle introduction, Macmillan, 1997
o Zienkiewicz, O.C.; Taylor, R.L., The finite element method: 1 basic formulation and linear problems, Elsevier, 2005
o Huerta, A.; Sarrate, J.; Rodríguez-Ferran, A. Métodos numéricos. Introducción, aplicaciones y programación. Edicions UPC, 1999
o Trefethen, L.N. & Bau, D., Numerical linear algebra, SIAM, 1996
o Saad, Y., Iterative methods for sparse linear systems. Academic Press, 2000
o Burden, R.L.; Faires, J.D. Análisis numérico. Sexta edición. International Thomson Editores, 1998.

STUDY LOAD

Type	Hours	Percentage
Self study	80,0	63.95
Hours large group	25,5	20.38
Hours small group	9,8	7.83
Hours medium group	9,8	7.83

Total learning time: 125.1 h

CONTENTS

Introduction

Description:
* Problems to be solved: Boundary problems and Initial value problems.
* PDEs, boundary conditions and initial conditions
* Elliptic, parabolic and hyperbolic problems
* Balance and equilibrium.

Examples of physical problems.

Full-or-part-time: 4h 48m
Theory classes: 1h
Practical classes: 1h
Self study : 2h 48m

Basic concepts of FEM

Description:
* Type of approximation: piecewise polynomials / spline
* Strong form
* Weighted residuals: dealing with boundary conditions
* Point collocation, Least squares and Galerkin formulations
* Weak form

Examples
Problems

Full-or-part-time: 9h 36m
Theory classes: 1h
Practical classes: 1h
Laboratory classes: 2h
Self study : 5h 36m

Poisson problem in 1D

Description:
* Space and functional discretizations
* Weak form: resulting linear system

Examples
Problems

Full-or-part-time: 16h 48m
Theory classes: 2h
Practical classes: 1h
Laboratory classes: 4h
Self study : 9h 48m

Linear Elasticity 1D

Description:
* Elementary stiffness matrix
* Assembly in 1D
* Prescribed displacements

Isoparametric elements
Examples

Full-or-part-time: 10h 48m
Theory classes: 2h
Practical classes: 1h
Laboratory classes: 1h 30m
Self study : 6h 18m

Poisson problem in 2D and 3D

Description:
* Basic equations
* Weak form
* FEM discretization
* Boundary conditions

Examples

Full-or-part-time: 7h 11m
Theory classes: 2h
Practical classes: 1h
Self study : 4h 11m

Quadratic and higher order elements

Description:
* 2D/3D elements
* Isoparametric elements
* Numerical integration
* General solution of Poisson equation with FEM

Examples

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study : 5h 36m

Linear Elasticity 2D

Description:
* Basic equations
* Principle of virtual work (PVW)
* FEM discretization

Examples

Full-or-part-time: 12h
Theory classes: 2h
Practical classes: 2h
Laboratory classes: 1h
Self study : 7h

Convergence and error estimates

Description:
* A priori error estimates:
convergence ratio
* A posteriori error estimates
* Mesh adaptivity

Examples

Full-or-part-time: 9h 36m
Theory classes: 2h
Practical classes: 2h
Self study : 5h 36m

Transient problems

Description:
* Space-time splitting: the method of lines
* Direct time integration, stability
* Newmark method* Modal analysis

Examples
Problems

Full-or-part-time: 9h 36m
Theory classes: 1h
Practical classes: 2h
Laboratory classes: 1h
Self study : 5h 36m

Introduction to FEM programming

Description:
MAT FEM and MAT FEM cal programs

Full-or-part-time: 3h 35m
Laboratory classes: 1h 30m
Self study : 2h 05m

Application of FEM to engineering problems

Description:
Application of MEF to engineering problems
Examples

Full-or-part-time: 12h
Practical classes: 1h
Laboratory classes: 4h
Self study : 7h

Boundary conditions

Description:
Dirichlet and Neumann boundary conditions

Full-or-part-time: 2h 24m
Practical classes: 1h
Self study : 1h 24m

GRADING SYSTEM

The mark of the course is obtained from the ratings of continuous assessment and the evaluation tests.

Continuous assessment consist in several homeworks, carried out during the year. Assistance to the classes will also be evaluated.

The evaluation tests consists of a part with questions about concepts associated with the learning objectives of the course with regard to knowledge or understanding, and a part with a set of application exercises.

EXAMINATION RULES.

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

BIBLIOGRAPHY

Basic:
- Oñate, E.; Diez, P.; Zarate, F.; Larese, A. Introduction to the finite element method [on line]. 2008 [Consultation: 17/03/2021]. Available on: http://hdl.handle.net/2117/184007.
- Zienkiewicz, O.C.; Taylor, R.L.; Zhu, J.Z. The Finite element method: its basis & fundamentals. Amsterdam: Elsevier Butterworth-Heinemann, 2013. ISBN 9781856176330.
- Reddy, J.N. Introduction to the finite element method. 4th ed. New York: McGraw-Hill, 2019. ISBN 9781259861901.