Course Unit	Computational Mechanics	Field of study	Solids Mechanics and Structures
Master in	Mechanical Engineering	School	School of Technology and Management
Academic Year	2023/2024	Year of study	1
Level	2-1	ECTS credits	6.0
Type	Semestral	Semester	2
Code	5071-793-1201-00-23		

Workload (hours)	162	Contact hours	T	-	TP	30	PL	30	TC	-	S	-	E	-	OT	-	O	-

T - Lectures; TP - Lectures and problem-solving; PL - Problem-solving, project or laboratory; TC - Fieldwork; S - Seminar; E - Placement; OT - Tutorial; O - Other

Name(s) of lecturer(s)	Paulo Alexandre Gonçalves Piloto

Learning outcomes and competences

At the end of the course unit the learner is expected to be able to:
1. Understand and apply finite element formulations.
2. Formulate bar, beam, two-dimensional and three-dimensional finite elements.
3. Understand and apply plate and shell finite element formulations.
4. Understand the finite element method and interpret the obtained solutions.
5. Understand the basic steps of a finite element code organization in a simple program.
6. Use commercial finite element software for engineering applications.

Prerequisites

Before the course unit the learner is expected to be able to:
1. Differential and integral calculus, numerical meth. , programming, mech. of materials, solid mech.
2. Understand oral and written english.

Course contents

Basic concepts of matrix analysis of structures. Variational principles. Formulation of bar, beam, two and three dimensional elasticity, plate and shell elements. Element assembly. Matrix and isoparametric formulations. Numerical integration. Interpolation of displacements, geometry and strains. Basic structure of a finite element code. Convergence of the solution and error estimation. Computational applications to structural, thermal and fluid flow problems.

Course contents (extended version)

1. Chapter 1 - Stages of the FEM. Bar element.
   - Introduction, advantages and applications of the finite element method (FEM).
   - Basic concepts in matrix analysis of structures. Types of analysis.
   - Fundamental steps in the FEM. Phases of the method.
   - Mathematical model formulation.
   - Discrete mathematical models. Static and dynamic formulations.
   - Stiffness matrix and element assembly.
   - Continuous mathematical models. Variational formulation.
   - Bar element formulation.
   - Matrix formulation of the element equations.
   - Isoparametric formulation and numerical integration.
2. Chapter 2 - Finite element codes
   - Basic organization of a finite element code.
   - FEM general methodology.
   - Shape functions. Interpolation of displacements.
   - Displacement and strain fields.
   - Stress field. Constitutive models.
   - Solution of the FEM equations.
   - FEM convergence requirements and error types.
   - Optimal points for stress calculations.
3. Chapter 3 – Beam elements
   - Euler-Bernoulli beam elements.
   - Formulation of Timoshenko beam elements.
   - Reduced integration and alternative solutions for the shear locking problem.
4. Chapter 4 - 2D and 3D formulations
   - Two and three dimensional finite elements in elasticity.
   - Finite elements formulation. Lagrangian and Serendipity elements.
   - Numerical integration.
   - Application of plate and shell finite elements: Kirchhoff and Reissner-Mindlin theories.
5. Chapter 5 - Computer Applications in Engineering
   - Structural engineering problems, thermal and fluid flow (ANSYS)

Recommended reading

1. Onãte E. , Cálculo de estructuras por el Método de Elementos Finitos, Centro Internacional de Métodos Numéricos en Ingeniería, Barcelona, 1995.
2. Moaveni, S. , Finite Element Analysis, Theory and Application with Ansys, 2nd Edition, Prentice Hall, 2003.
3. Zienkiewicz OC, Taylor RL. , The finite element method. Vols. 1, 2. Oxford: Butterworth, 2000.
4. Krishnamoorthy CS. , Finite Element Analysis–Theory and Programming, Tata McGrawHill, New Delhi, 1997.
5. Bathe KJ. , Finite Element Procedures. New Jersey: Prentice Hall, 1996.

Teaching and learning methods

Theoretical classes with methodologies for solving physical problems. Practical classes for solving physical problems. Working projects and problems to be solved in the off-site period. Classes can be complemented by a course on the COURSERA platform, promoted by the University of Michigan, entitled "Finite Element Method applied to Physics Problems.

Assessment methods

1. FINAL season: Distributed assessment. - (Regular, Student Worker) (Final, Supplementary)
   - Practical Work - 80% (3 working projects with oral presentation. Each with 26. 6(6)% weight for final mark.)

Assessment methods

- Final Written Exam - 20%

2. SPECIAL season - (Regular, Student Worker) (Special)
   - Final Written Exam - 100% (Final examination with 2, 0 hours maximum duration, with100% weight for final mark.)
3. FINAL: Exam for Labor students - (Student Worker) (Final)
   - Final Written Exam - 100% (Labour students may choose final exam. , with 2, 0 hours maximum duration, with100% for final mark.)

Language of instruction

English

Electronic validation

Paulo Alexandre Gonçalves Piloto	Debora Rodrigues de Sousa Macanjo Ferreira	Luís Manuel Ribeiro Mesquita	José Carlos Rufino Amaro
27-02-2024	27-02-2024	27-02-2024	02-03-2024