INTERNATIONAL
CAMPUS OF
EXCELLENCE

POLITÉCNICA

E.T.S. de Ingenieros de
Caminos, Canales y Puertos

# ANX-PR/CL/001-01

# LEARNING GUIDE

**SUBJECT**

**43000445 - Computational Mechanics**

**DEGREE PROGRAMME**

04AM - Master Universitario Ingenieria De Estructuras, Cimentaciones Y Materiales

**ACADEMIC YEAR & SEMESTER**

2019/20 - Semester 2

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# 1. Description

## 1.1. Subject details

| | |
|---|---|
| **Name of the subject** | 43000445 - Computational Mechanics |
| **No of credits** | 4.5 ECTS |
| **Type** | Optional |
| **Academic year ot the programme** | First year |
| **Semester of tuition** | Semester 2 |
| **Tuition period** | February-June |
| **Tuition languages** | English |
| **Degree programme** | 04AM - Master Universitario Ingenieria De Estructuras, Cimentaciones Y Materiales |
| **Centre** | 04 - Escuela Tecnica Superior de Ingenieros de Caminos, Canales y Puertos |
| **Academic year** | 2019-20 |

# 2. Faculty

## 2.1. Faculty members with subject teaching role

| Name and surname | Office/Room | Email | Tutoring hours * |
|---|---|---|---|
| Juan Carlos Garcia Orden (Subject coordinator) | ETSI Caminos | juancarlos.garcia@upm.es | Tu - 11:00 - 13:00<br>W - 11:00 - 13:00<br>F - 11:00 - 13:00 |

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

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# 3. Prior knowledge recommended to take the subject

## 3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

## 3.2. Other recommended learning outcomes

- Some programing experience in any high-level language is highly desirable. Specifically, programming skills with Matlab/Octave are very valuable, since most of the proposed exercises will demand programming in this environment.

# 4. Skills and learning outcomes *

## 4.1. Skills to be learned

CB6 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB9 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CE13 - - Capacidad para el ejercicio profesional de alta especialización o para la investigación predoctoral mediante la utilización de recursos de modelización predictiva en Análisis y diseño estructural en régimen dinámico y/o no lineal.

CG1 - Polivalencia para extender a ámbitos afines las competencias generales adquiridas en el ámbito temático del título.

CG4 - Capacidad de comunicación académica de contenido técnico y científico, oral y escrita en lengua inglesa.

CT3 - Compromiso y capacidad de aplicación de los estándares de deontología en investigación y ejercicio profesional avanzado

## 4.2. Learning outcomes

RA13 - Sintetiza e integra con polivalencia y autonomía las competencias específica de formación científico-técnica para iniciación en I+D+i, para la alta especialización y para la investigación doctoral.

RA9 - Participa en debates en lengua inglesa

RA8 - Utiliza con eficacia recursos de modelización predictiva en una o más de las materias del módulo

RA2 - Presenta comunicaciones orales, escritas y gráficas, estructurada y argumentadamente, en lengua española e inglesa

RA4 - Utiliza con eficacia recursos de información y comunicación

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

# 5. Brief description of the subject and syllabus

## 5.1. Brief description of the subject

The main objective of this course is to present the main numerical methods applied to computational mechanics and their corresponding mathematical analysis. At the end of the course a student should have become familiar with the most important algorithms and must know how to choose the most suitable for certain common problems of structural engineering. Concrete objectives are:

1. Acquire the necessary knowledge of programming in Matlab / Octave that allows to apply the different methods studied for the solution of mechanical problems

2. To know the basic concepts related to the numerical techniques for the solution of structural problems.

3. To know and to program the most common algorithms for the numerical solution of linear and nonlinear static problems

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4. To know and to program the most common algorithms for the numerical solution of nonlinear dynamical problems

## 5.2. Syllabus

1. Introduction to Matlab/Octave

2. Basic concepts on numerical methods. Floating-point representation of real numbers. Roundoff errors

3. Statics of solids and structures

    3.1. Nonlinear static problems. Systems of non-linear algebraic equations

    3.2. Linear static problems. Systems of linear algebraic equations

        3.2.1. Small-medium size models. Direct methods

        3.2.2. Large models. Iterative methods

4. Nonlinear dynamics of solids and structures

    4.1. General concepts about the numerical solution of systems of nonlinear ordinary differential equations.Direct integration methods.

    4.2. One-step methods

    4.3. Multi-step methods

    4.4. Structural methods

    4.5. Geometric methods

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# 6. Schedule

## 6.1. Subject schedule*

| Week | Face-to-face classroom activities | Face-to-face laboratory activities | Other face-to-face activities | Assessment activities |
|---|---|---|---|---|
| 1 | **Presentation** <br> Duration: 01:00 <br> Lecture <br><br> **Tema 1. Introduction to Matlab/Octave (I)** <br> Duration: 02:00 <br> Lecture | | | |
| 2 | **Tema 1. Introduction to Matlab/Octave (II)** <br> Duration: 01:00 <br> Lecture <br><br> **Tema 2. Basic concepts about numerical methods. Floating point representation of real numbers. Roundoff errors** <br> Duration: 02:00 <br> Lecture | | | |
| 3 | **Tema 3.1, Nonlinear static problems (I)** <br> Duration: 02:00 <br> Lecture | | | **Oral presentations, Unit 1** <br> Individual presentation <br> Continuous assessment <br> Duration: 01:00 |
| 4 | **Tema 3.1. Nonlinear static problems (II)** <br> Duration: 02:00 <br> Lecture | | | **Oral presentations, Unit 2** <br> Individual presentation <br> Continuous assessment <br> Duration: 01:00 |
| 5 | **Tema 3.1. Nonlinear static problems (III)** <br> Duration: 03:00 <br> Lecture | | | |
| 6 | **Tema 3.2.1. Linear static problems (I). Small-medium size models. Direct methods** <br> Duration: 02:00 <br> Lecture | | | **Oral presentations, Unit 3.1** <br> Individual presentation <br> Continuous assessment <br> Duration: 01:00 |
| 7 | **Tema 3.2.1. Linear static problems (II). Precision** <br> Duration: 03:00 <br> Lecture | | | |
| 8 | **Tema 3.2.2. Linear static problems (III). Large models. Iterative methods.** <br> Duration: 03:00 <br> Lecture | | | |
| 9 | **Tema 3.2.2. Linear static problems (iV). Large models. Iterative methods** <br> Duration: 02:00 <br> Lecture | | | **Oral presentations, Unit 3.2.1.** <br> Individual presentation <br> Continuous assessment <br> Duration: 01:00 |

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| | | | | |
|---|---|---|---|---|
| 10 | **Tema 4.1. Nonlinear dynamics. General concepts**<br>Duration: 03:00<br>Lecture | | | |
| 11 | | | | |
| 12 | **Tema 4.2. Nonlinear dynamics. One-step methods**<br>Duration: 02:00<br>Lecture | | | **Oral presentations, Unit 3.2.2**<br>Individual presentation<br>Continuous assessment<br>Duration: 01:00 |
| 13 | **Tema 4.3. Nonlinear dynamics. Multi-step methods**<br>Duration: 03:00<br>Lecture | | | |
| 14 | **Tema 4.4. Nonlinear dynamics. Structural methods (I)**<br>Duration: 02:00<br>Lecture | | | **Oral presentations, Units 4.1, 4.2**<br>Individual presentation<br>Continuous assessment<br>Duration: 01:00 |
| 15 | **Tema 4.4. Nonlinear dynamics. Structural methods (II)**<br>Duration: 02:00<br>Lecture<br><br>**Tema 4.5. Geometric methods (I)**<br>Duration: 01:00<br>Lecture | | | |
| 16 | **Tema 4.5. Geometric methods (II)**<br>Duration: 02:00<br>Lecture | | | **Oral presentations, Units 4.3, 4.4**<br>Individual presentation<br>Continuous assessment<br>Duration: 01:00 |
| 17 | | | | **Final exam**<br>Problem-solving test<br>Final examination<br>Duration: 03:00 |

The independent study hours are training activities during which students should spend time on individual study or individual assignments.

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The subject schedule is based on a previous theorical planning of the subject plan and might go to through experience some unexpected changes along throughout the academic year.

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# 7. Activities and assessment criteria

## 7.1. Assessment activities

### 7.1.1. Continuous assessment

| Week | Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|------|-------------|----------|------|----------|--------|---------------|------------------|
| 3 | Oral presentations, Unit 1 | Individual presentation | Face-to-face | 01:00 | 0% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |
| 4 | Oral presentations, Unit 2 | Individual presentation | Face-to-face | 01:00 | 10.83% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |
| 6 | Oral presentations, Unit 3.1 | Individual presentation | Face-to-face | 01:00 | 10.83% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |
| 9 | Oral presentations, Unit 3.2.1. | Individual presentation | Face-to-face | 01:00 | 10.83% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |
| 12 | Oral presentations, Unit 3.2.2 | Individual presentation | Face-to-face | 01:00 | 10.83% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |
| 14 | Oral presentations, Units 4.1, 4.2 | Individual presentation | Face-to-face | 01:00 | 10.83% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |

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| 16 | Oral presentations, Units 4.3, 4.4 | Individual presentation | Face-to-face | 01:00 | 10.83% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |

### 7.1.2. Final examination

| Week | Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|------|-------------|----------|------|----------|--------|---------------|------------------|
| 17 | Final exam | Problem-solving test | No Presential | 03:00 | 100% | / 10 | CB9 CG1 CG4 CT3 CE13 CB6 |

### 7.1.3. Referred (re-sit) examination

No se ha definido la evaluación extraordinaria.

## 7.2. Assessment criteria

Students will be evaluated, by default, through continuous evaluation. The student wishing to give up the continuous evaluation and to opt for the evaluation by final exam (formed by one or more evaluation activities of the course), must write through the platform Moodle to the coordinator of the course before the seventh week.

The evaluation will check if the students have acquired the competences of the course. Therefore, the final exam will use the same types of evaluation techniques used in the continuous evaluation (EX), and will be carried out at the final dates and times approved by the Academic Board for the current course and semester, except those activities of evaluation of learning results of difficult qualification in a final exam. In this case, these evaluation activities may be carried out throughout the course.

The evaluation in the extraordinary call will be made exclusively through the final exam procedure.

The grade of the course through continuous evaluation will be determined according to two elements: 1) Attendance and participation (35% of the grade); 2) Exercises and problems proposed and presented throughout the course (65% of the grade).

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# 8. Teaching resources

## 8.1. Teaching resources for the subject

| Name | Type | Notes |
|------|------|-------|
| García Orden, J.C. "Computational Mechanics" | Bibliography | Course notes |
| Página web de la asignatura | Web resource | https://moodle.upm.es/titulaciones/oficiales/course/view.php?id=4366 |
| J.W. Eaton, David Bateman, and Soren Hauberg. GNU Octave. A high- level interactive language for numerical computations | Bibliography | |
| A. Quarteroni and F. Saleri. Scientific Computing with MATLAB and Octave. Springer, 2006. | Bibliography | |
| A. Quarteroni, R. Sacco, and F. Saleri. Numerical Mathematics. Texts in Applied Mathematics. Springer, 2007. | Bibliography | |
| J.W. Demmel, Applied numerical linear algebra, SIAM, Philadelphia, 1997. | Bibliography | |
| T.R.J. Hughes. The Finite Element Method. Prentice Hall, 1987. | Bibliography | |
| Javier Bonet and Richard D. Wood. Nonlinear continuum mechanics for finite element analysis. Cambridge University Press, second edition, 2008. | Bibliography | |
| Uri M. Ascher and Linda R. Petzold. Computer Methods for Ordinary Differential Equations and Differential-Algebraic Equations. SIAM, Philadelphia, USA, 1998. | Bibliography | |

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| M. Geradin and D. Rixen. Mechanical vibrations. Wiley, 1997. | Bibliography | |
|---|---|---|