ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

45000123 - Numerical Simulation

DEGREE PROGRAMME

04MI - Grado En Ingenieria De Materiales

ACADEMIC YEAR & SEMESTER

2025/26 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	45000123 - Numerical Simulation
No of credits	6 ECTS
Type	Compulsory
Academic year ot the programme	Third year
Semester of tuition	Semester 5
Tuition period	September-January
Tuition languages	English
Degree programme	04MI - Grado en Ingenieria de Materiales
Centre	04 - E.T.S. De Ing. De Caminos Canales Y P.
Academic year	2025-26

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Alvaro Ridruejo Rodriguez		alvaro.ridruejo@upm.es	M - 14:30 - 16:30 W - 14:30 - 16:30
Javier Segurado Escudero (Subject coordinator)		javier.segurado@upm.es	M - 14:30 - 16:30 W - 14:30 - 16:30

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

2.2. Research assistants

Name and surname	Email	Faculty member in charge
Alvarez Morales, Gonzalo	g.alvarezm@upm.es	Segurado Escudero, Javier

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

- MecÁnica De Materiales I

- MecÁnica De Materiales Ii

- MatemÁticas Ii

- MatemÁticas I

3.2. Other recommended learning outcomes

- Some previous relation with a programming language will be very useful, matlab, python, C, fortran

4. Skills and learning outcomes *

4.1. Skills to be learned

CE 2. - Saber modelizar el comportamiento (mecánico, electrónico, químico o biológico) de los materiales y su integración en componentes y dispositivos.

CG 1 - Uso de la lengua inglesa

CG 10 - Adaptación a nuevas situaciones

CG 4 - Uso de las Tecnologías de la Información y de las Comunicaciones

CG 9 - Capacidad de trabajo interdisciplinar

4.2. Learning outcomes

RA101 - Ability in using MATLAB or some open source substitute as OCTAVE as a programmer

RA100 - Wide overview of different numerical approaches to solve common mathematical problems

RA98 - Ability to translate a formula or model to a programming language to be solved in a computer

RA99 - Ability to understand and use the basic concepts of programming: variables, loops, conditions, etc

* 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

This is a fundamental subject for Engineers in general and Materials Engineers in particular.

As a summary, in this subject we will teach the basic skills to allow the student to implement and solve equations, mathematical problems and simple physical/engineering models using a computer and a programming language, in this case MATLAB/Octave/Python.

The particular objectives are:

- Learning the fundamentals of computer programming: mathematical operations, loops, conditionals, etc
- Introduction to a specific Math-oriented programming language: Matlab/Octave
- Learning and programming of some basic algorithms for solving algebraical equations, numerical integration, etc
- Introduction to Monte-Carlo (probabilistic) based simulation methods
- Introduction to the numerical resolution of Ordinary Differential Equations: Implicit and explicit Euler methods
- Introduction to the Finite Element Method and its implementation in a programming language

5.2. Syllabus

1. Introduction Introduction to the subject. General description contents and subject
2. Fundamentals of programming: introduction to MATLAB/OCTAVE/Python
3. Systems of algebraic equations
   - 3.1. Linear systems of equations. Direct methods.
   - 3.2. Non Linear systems of equations. Bisection method, Newton-Raphson, etc
4. Ordinary differential equations
   - 4.1. First order linear Ordinary Differential equations: Euler methods First order linear Ordinary Differential equations: Euler methods
   - 4.2. Systems of Ordinary Differential equations and higher order equations
5. Partial Differential Equations: The Finite Element Method
   - 5.1. Introduction: PDEs and boundary value problems
   - 5.2. Poisson Equation and Galerkin approach
   - 5.3. The FEM method
6. Probabilistic methods
   - 6.1. Monte Carlo simulation. An introduction
   - 6.2. Random walk
   - 6.3. Kinetic Monte Carlo
7. Other simulation techniques

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**Introduccion** Duration: 01:30 Lecture **T2: Introduction to programming** Duration: 02:30 Lecture			
2	**T2: Introduction to programming** Duration: 02:30 Lecture **T2: Introduction to programming** Duration: 01:30 Laboratory assignments			**Test on fundamental knowledge I** **Multiple choice test** Online test Progressive assessment and Global Examination Presential Duration: 01:30
3	**T2: Introduction to programming** Duration: 01:30 Lecture **T2: Introduction to programming** Duration: 01:30 Laboratory assignments **T2: Introduction to programming** Duration: 01:00 Laboratory assignments			
4	**T3: Systems of algebraical equations** Duration: 01:30 Lecture **T3: Systems of algebraical equations** Duration: 01:00 Lecture **T3: Systems of algebraical equations** Duration: 01:30 Problem-solving class			
5	**T3: Systems of algebraical equations** Duration: 01:30 Lecture **T3: Systems of algebraical equations** Duration: 01:00 Lecture **T3: Systems of algebraical equations** Duration: 01:30 Problem-solving class			**Test on programming** Problem-solving test Progressive assessment Presential Duration: 01:00

6	**T4: Ordinary differential equations** Duration: 01:30 Lecture **T4: Ordinary differential equations** Duration: 01:00 Lecture **T4: Ordinary differential equations** Duration: 01:30 Laboratory assignments			
7	**T5: Partial Differential Equations: The Finite Element Method** Duration: 02:30 Lecture **T5: Partial Differential Equations: The Finite Element Method** Duration: 01:30 Laboratory assignments			
8	**T5: Partial Differential Equations: The Finite Element Method** Duration: 02:30 Lecture **T5: Partial Differential Equations: The Finite Element Method** Duration: 01:30 Laboratory assignments			**First partial exam** Problem-solving test Progressive assessment Presential Duration: 02:30
9	**T5: Partial Differential Equations: The Finite Element Method** Duration: 02:30 Lecture **T5: Partial Differential Equations: The Finite Element Method** Duration: 01:30 Laboratory assignments			
10	**T5: Partial Differential Equations: The Finite Element Method** Duration: 02:30 Lecture **T5: Partial Differential Equations: The Finite Element Method** Duration: 01:30 Laboratory assignments			**Test on fundamental knowledge II** **Multiple choice test** Online test Progressive assessment and Global Examination Presential Duration: 01:30
11	**T6: Probablistic models** Duration: 02:30 Lecture **T6: Probablistic models** Duration: 02:30 Lecture			

12	**T6: Probablistic models** Duration: 02:30 Lecture **T6: Probablistic models** Duration: 01:30 Problem-solving class			
13	**T6: Probablistic models** Duration: 02:30 Lecture **T5: Probablistic models** Duration: 01:30 Problem-solving class			
14	**T5: Probablistic models** Duration: 02:30 Lecture **T5: Probablistic models** Duration: 01:30 Problem-solving class			
15	**T5: Probablistic models** Duration: 02:30 Lecture **T5: Probablistic models** Duration: 01:30 Problem-solving class			
16				**Second partial exam** Problem-solving test Progressive assessment Presential Duration: 02:30 **Group Homework** Group work Progressive assessment Not Presential Duration: 12:00
17				**Final exam covering all the subject** Problem-solving test Global examination Presential Duration: 03:00 **Test on fundamental knowledge III** **Multiple choice test** Online test Progressive assessment and Global Examination Presential Duration: 01:30

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.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
2	Test on fundamental knowledge I Multiple choice test	Online test	Face-to-face	01:30	%	7 / 10	CG 4
5	Test on programming	Problem-solving test	Face-to-face	01:00	12.5%	/ 10	CG 4 CG 9 CG 1 CG 10
8	First partial exam	Problem-solving test	Face-to-face	02:30	37.5%	3 / 10	CE 2. CG 4
10	Test on fundamental knowledge II Multiple choice test	Online test	Face-to-face	01:30	%	7 / 10	
16	Second partial exam	Problem-solving test	Face-to-face	02:30	37.5%	3 / 10	CE 2. CG 4
16	Group Homework	Group work	No Presential	12:00	12.5%	/ 10	CG 10 CG 9
17	Test on fundamental knowledge III Multiple choice test	Online test	Face-to-face	01:30	%	7 / 10	

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
2	Test on fundamental knowledge I Multiple choice test	Online test	Face-to-face	01:30	%	7 / 10	CG 4
10	Test on fundamental knowledge II Multiple choice test	Online test	Face-to-face	01:30	%	7 / 10	
17	Final exam covering all the subject	Problem-solving test	Face-to-face	03:00	100%	5 / 10	CG 4 CE 2. CG 1
17	Test on fundamental knowledge III Multiple choice test	Online test	Face-to-face	01:30	%	7 / 10	

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Extraordinary exam covering the full subject	Problem-solving test	Face-to-face	03:00	100%	5 / 10	CE 2. CG 4 CG 9 CG 1
Test on fundamental knowledge IV Mutile choice test	Online test	Face-to-face	01:30	%	7 / 10	CG 4

7.2. Assessment criteria

Continuous evaluation:

It will consider two partial exams and complementary activities:

- The two partials will weight 75% of continuous evaluation. They will be done during classtime and will last 2.5h. They will be practical exercises to be resolved using a personal computer. The weight of each partial will be 50%
- The complementary activities will consist in (1) a first test about programming that will be done during a class by the beginning of October, this part will be 12.5% of the continuous evaluation (2) A homework exercise that will be proposed near December, this part will be 12.5% of the continuous evaluation.
- A fundamental knowledge test (high-school and first year of the degree level) over subjects of chemistry, physics and mathematics has to be passed (minimum grade of 7). There will be three opportunities to pass the test on fundamentals on the continuous assessment evaluation and a fourth opportunity will be provided for the re-sit examination.
- The subject will be passed (no need of final exam) with average global score higher than 50%. For passing the subject, a minimum mark of 30% in each partial is required. And the fundamental knowledge exam should be passed (minimum grade 7) in any of its sittings.

Final evaluation:

- It will consist on a final exam covering the whole program. Marks in complementary activities will not be considered in the final evaluation.
- In order to pass the subject through the final evaluation, the fundamental knowledge test has to be passed (minimum grade 7) in any of its sittings.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Scientific computing with MATLAB and OCTAVE A. Quarteroni and F. Saleri, Springler 2006 (Spanish version also available)	Bibliography	Book covering T2,T3 and T4, and some parts of T5 and T6
A first course in Finite Elements, Jacob Fish and Ted Belytschko, Wiley, 2007	Bibliography	A nice introductory book to Finite Elements, covering by far T6
PDF presentations	Others	All the theory explained and examples will be available as pdf presentations. It is not a book, but short notes so complementing with class explanations and/or other text is mandatory

9. Other information

9.1. Other information about the subject

* Esta asignatura contribuye a los siguientes Objetivos de Desarrollo sostenible de la ONU, a través de sus procesos de aprendizaje y con los resultados obtenidos:

En particular,

4. Garantizar una educación de calidad inclusiva y equitativa, y promover las oportunidades de aprendizaje permanente para todos:

Se contribuye mediante el uso de software libre y gratuito (octave) como herramienta de aprendizaje y profesional en el futuro.

5. Alcanzar la igualdad entre los géneros y empoderar a todas las mujeres y niñas.

Se contribuye introduciendo esta asignatura, clásicamente una asignatura STEM con poco tirón para las estudiantes, como obligatoria . De esta forma se da una formación básica en una tecnología útil y que clásicamente ha sido uttilizada por hombres.

9. Desarrollar infraestructuras resilientes, promover la industrialización inclusiva y sostenible, y fomentar la innovación.

El uso de técnicas de simulación permite avanzar hacia una mejor y más eficiente tecnología y es una de las

mayores áreas de innovación en materiales

* Se señala de que en caso de necesidad por razones sanitarias, las actividades docentes y de evaluación pasarán a tener lugar en modalidad telemática