# ANX-PR/CL/001-01

# LEARNING GUIDE

## SUBJECT

**43000607 - DiseÑo Estructural**

## DEGREE PROGRAMME

04AN - Master Universitario En Ingenieria De Materiales

## ACADEMIC YEAR & SEMESTER

2023/24 - Semester 2

# Index

## Learning guide

# 1. Description

## 1.1. Subject details

| | |
|---|---|
| **Name of the subject** | 43000607 - Diseño Estructural |
| **No of credits** | 3 ECTS |
| **Type** | Optional |
| **Academic year ot the programme** | First year |
| **Semester of tuition** | Semester 2 |
| **Tuition period** | February-June |
| **Tuition languages** | English |
| **Degree programme** | 04AN - Master Universitario en Ingenieria de Materiales |
| **Centre** | 04 - Escuela Tecnica Superior De Ingenieros De Caminos, Canales Y Puertos |
| **Academic year** | 2023-24 |

# 2. Faculty

## 2.1. Faculty members with subject teaching role

| Name and surname | Office/Room | Email | Tutoring hours * |
|---|---|---|---|
| Carlos Daniel Gonzalez Martinez (Subject coordinator) | Materials Dpt. | c.gonzalez@upm.es | Th - 15:00 - 17:00 |
| Alvaro Ridruejo Rodriguez | Materials Dpt. | alvaro.ridruejo@upm.es | Th - 15:00 - 17:00 |
| Javier Segurado Escudero | Materials Dpt. | javier.segurado@upm.es | Th - 15:00 - 17:00 |

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

## 3. Prior knowledge recommended to take the subject

### 3.1. Recommended (passed) subjects

- Modelling And Simulation In Materials Science And Engineering

### 3.2. Other recommended learning outcomes

- Programming

- Mechanics, materials behaviour

## 4. Skills and learning outcomes *

### 4.1. Skills to be learned

CE1 - Capacidad para aplicar los fundamentos científicos del comportamiento físico y químico de los materiales para relacionar causalmente sus propiedades fundamentales físicas y químicas con su comportamiento macroscópico y el de los productos con ellos realizados / Ability to apply the scientific foundations of the physical and chemical behavior of materials to correlate their fundamental physical and chemical properties with their macroscopic behavior and that of the products made with them.

CE2 - Uso de equipos y técnicas experimentales de caracterización de materiales (micro y macroestructura, comportamientos mecánico, eléctrico, y óptico) para identificar y analizar los diversos tipos de materiales / Use of equipment and experimental techniques for the characterization of materials (micro and macrostructure, mechanical, electrical, and optical behavior) to identify and analyze the various types of materials.

CE3 - Capacidad de diseñar, modelizar, evaluar, seleccionar, fabricar y utilizar materiales con propiedades específicas (estructurales y funcionales) para satisfa

CE4 - Autonomía para adquirir, analizar, actualizar y aplicar nuevos conocimientos, modelos y técnicas experimentales y numéricas en relación con la composición y estructura de los materiales, su caracterización física y química, sus procesos de fabricación, su utilización y aplicación científica y tecnológica, y su reciclado, reutilización y eliminación / Autonomy to acquire, analyze, update and apply new knowledge, models and experimental and numerical techniques related to the composition and structure of materials, their physical and chemical characterization, their manufacturing processes, their use and scientific and technological application, and their recycling, reuse and disposal

CE5 - Capacidad para planificar, explotar y gestionar técnicamente la selección, fabricación, procesado, utilización, reciclado, reutilización y eliminación de materiales, de forma respetuosa con el medio ambiente, de conformidad con la legislación nacional e internacional, y promoviendo el desarrollo sostenible y el bienestar de la sociedad / Ability to technically plan, exploit and manage the selection, manufacturing, processing, use, recycling, reuse and disposal of materials, in an environmentally friendly manner, in accordance with national and international legislation, and promoting sustainable development and well-being of the society

CE6 - Capacidad para controlar y modificar los mecanismos físicos y químicos que determinan las fases del ciclo de vida de los materiales, su durabilidad y su incidencia en el medioambiente con el fin de poder evaluar, controlar y mejorar la seguridad, durabilidad e integridad estructural de los materiales y los componentes fabricados con ellos / Ability to control and modify the physical and chemical mechanisms that determine the phases of the life cycle of materials, their durability and their impact on the environment in order to be able to evaluate, control and improve the safety, durability and structural integrity of materials and components made from them

CE7 - Manejo de herramientas de simulación numérica para diseño y análisis de materiales, desde la escala microscópica a la macroscópica / Management of numerical simulation tools for design and analysis of materials, from the microscopic to the macroscopic scale

CG1 - Uso de la lengua inglesa: Los alumnos son capaces de transmitir conocimientos y expresar ideas y argumentos de manera clara, rigurosa y convincente, tanto de forma oral como escrita, adaptándose a las características de la situación y de la audiencia / Use of the English Language: Students are able to transmit knowledge and express ideas and arguments in a clear, rigorous and convincing manner, both orally and in writing, adapting to the characteristics of the situation and the audience .

CG3 - Trabajo en equipo: Los alumnos desarrollan la capacidad para trabajar en equipo, integrarse y colaborar de forma activa en la consecución de objetivos comunes / Teamwork: Students develop the ability to work as a team, integrate and actively collaborate in achieving common goals.

CG6 - Respeto hacia el medio ambiente: Los alumnos desarrollan las mejores prácticas para interactuar con el entorno, de forma ética, responsable y sostenible, en orden a evitar o disminuir los efectos negativos que ocasiona la actividad humana, así como promover los beneficios que pueda generar la actividad profesional en el ámbito medioambiental, teniendo en cuenta sus implicaciones económicas y sociales / Respect for the environament: Students develop the best practices to interact with the environment, in an ethical, responsible and sustainable way, in order to avoid or reduce the negative effects caused by human activity, as well as promote the benefits that professional activity in the environmental field can generate, taking into account its economic and social implications.

CG8 - Resolución de problemas: Los estudiantes son capaces de reconocer, describir, organizar y analizar los elementos constitutivos de un problema para idear estrategias que permitan obtener, de forma razonada, una solución contrastada y acorde a ciertos criterios preestablecidos / Problem solving: Students are able to recognize,

describe, organize and analyze the constitutive elements of a problem to devise strategies that allow obtaining, in a reasoned way, a contrasting solution and according to certain pre-established criteria.

CG9 - 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

CG9 - Análisis y Síntesis: Los alumnos son capaces de reconocer y describir los elementos constitutivos de una realidad, y de proceder a organizar la información significativa según criterios preestablecidos adecuados a un propósito / Analysis and Synthesis: Students are able to recognize and describe the constituent elements of a reality, and to proceed to organize significant information according to pre-established criteria suitable for a purpose.

## 4.2. Learning outcomes

RA21 - Saber redactar informes técnicos

RA22 - Ser creativo, ejecutando el trabajo con responsabilidad y respeto a los demás

RA24 - aber utilizar y aplicar las técnicas y modelos matemáticos de simulación para predecir el comportamiento y evolución de los materiales, en sus aspectos mecánico, electrónico, químico o biológico

RA25 - Conocer, comprender y saber aplicar los fundamentos científicos del comportamiento de los materiales y la interrelación entre su estructura, propiedades, procesado y aplicaciones

RA28 - Design simple structural elements with different materials

RA1 - Saber comunicar conocimientos, procedimientos, resultados o técnicas relacionadas con el comportamiento y el uso de materiales

RA26 - Saber utilizar y aplicar las técnicas y modelos matemáticos de simulación para predecir el comportamiento y evolución de los materiales. Saber evaluar su seguridad, durabilidad e integridad estructural y la de los componentes fabricados con ellos

RA27 - Conocer, comprender y saber aplicar los fundamentos científicos del comportamiento de los materiales

* 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 aim of this course is to provide the students with an overview of the current development in three main areas within the field of design of materials for structural applications:

- Mechanical behavior of engineering materials: elasticity, plasticity, creep, fatigue, and fracture.
- Simulation strategies for design and simulation of structural materials: metals and structural composites. Finite element modeling.
- Engineering optimization and constrained designs. Topological optimization and rapid prototyping.
- Metamaterials, cellular structures, and scaffolds.

## 5.2. Syllabus

1. Introduction to structural design of materials

2. Mechanical behaviour of structural materials I (elasticity, plasticity & visco)

3. Mechanical behaviour of structural materials II (fracture and fatigue)

4. Design of simple structural members under tension, compression, shear and bending

5. Simulation strategies for structural materials. Finite element modelling.

6. Simulation strategies for structural materials. Beams (1D), plates (2D), solids (3D). Introduction to finite element code

7. Topological Optimization I

8. Topological Optimization II

9. Metamaterials, cellular materials and scaffolds

10. Rapid prototyping & 3D printing. Practical examples

11. Simulation of structural composites I: Microstructures design + FEM laboratory

12. Simulation of structural composites II: Classical Laminate Theory + FEM laboratory

13. Simulation of structural metals I: Microstructures design + FEM laboratory

14. Simulation of structural metals II: Plastic Behaviour + FEM laboratory

15. Exam

# 6. Schedule

## 6.1. Subject schedule*

| Week | Classroom activities | Laboratory activities | Distant / On-line | Assessment activities |
|---|---|---|---|---|
| 1 | **Introduction on structural design in engineering.**<br>Duration: 02:00<br>Lecture | | | |
| 2 | **Introduction and analysis of structural behavior of materials. Basics of Elasticity, Plasticity and Viscous (time-dependent) behaviour**<br>Duration: 01:30<br>Lecture | **Practical exercises of mechanical behaviour of materials**<br>Duration: 00:30<br>Problem-solving class | | |
| 3 | **Introduction and analysis of structural behavior of materials. Basics of fracture, and fatigue behaviour**<br>Duration: 01:30<br>Lecture | **Practical exercises of mechanical behaviour of materials**<br>Duration: 00:30<br>Problem-solving class | | |
| 4 | **Design of simple structural members in tension, compression, shear and bending**<br>Duration: 01:30<br>Lecture | **Practical exercises of design of simple elements**<br>Duration: 00:30<br>Problem-solving class | | **Moodle Exercise on Mechanical Behaviour of Materials**<br>Online test<br>Continuous assessment<br>Presential<br>Duration: 00:30 |
| 5 | **Simulations strategies for structural materials. Finite element modelling**<br>Duration: 02:00<br>Lecture | | | |
| 6 | **Simulations strategies for structural materials. Beams (1D), plates (2D) and solids (3D)**<br>Duration: 01:00<br>Lecture | | | **Moodle Exercise on Structural Design of Simple Members**<br>Online test<br>Continuous assessment<br>Presential<br>Duration: 00:30 |
| 7 | | **Hands on with FEM software**<br>Duration: 02:00<br>Laboratory assignments | | |
| 8 | **Topological optimization I. Introduction and algorithms**<br>Duration: 02:00<br>Lecture | | | |
| 9 | **Topological optimization II. Implementation**<br>Duration: 00:30<br>Laboratory assignments | **Topological Optimization: Hands On with Software**<br>Duration: 01:30<br>Laboratory assignments | | |

| | | | | |
|---|---|---|---|---|
| 10 | **Rapid Prototyping and 3D printing**<br>Duration: 02:00<br>Lecture | | | |
| 11 | **Metamaterials, cellular structures and scaffolds**<br>Duration: 02:00<br>Lecture | | | |
| 12 | **Design of composite materials: Microstructure**<br>Duration: 01:00<br>Lecture | **Microstructures analysis by FEM**<br>Duration: 01:00<br>Laboratory assignments | | |
| 13 | **Design of composite materials: Laminate**<br>Duration: 01:00<br>Lecture | **Laminate analysis by FEM**<br>Duration: 01:00<br>Laboratory assignments | | |
| 14 | **Design of metals: Plasticity**<br>Duration: 01:00<br>Lecture | **Plasticity analysis of a structural member**<br>Duration: 01:00<br>Laboratory assignments | | |
| 15 | **Design of metals: Fracture**<br>Duration: 01:00<br>Lecture | **Fracture analysis of a structural member**<br>Duration: 00:30<br>Laboratory assignments | | **Simulation Report**<br>Individual work<br>Continuous assessment<br>Not Presential<br>Duration: 02:30 |
| 16 | | | | **Exam with the contents explained in the class**<br>Written test<br>Continuous assessment<br>Presential<br>Duration: 01:00 |
| 17 | | | | **Exam with the contents explained in the class**<br>Written test<br>Final examination<br>Presential<br>Duration: 01:00 |

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 schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

# 7. Activities and assessment criteria

## 7.1. Assessment activities

### 7.1.1. Assessment

| Week | Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|---|---|---|---|---|---|---|---|
| 4 | Moodle Exercise on Mechanical Behaviour of Materials | Online test | Face-to-face | 00:30 | 10% | 5 / 10 | CE3<br>CE4<br>CG8<br>CE1 |
| 6 | Moodle Exercise on Structural Design of Simple Members | Online test | Face-to-face | 00:30 | 10% | 5 / 10 | CG8<br>CE1<br>CE3<br>CE4 |
| 15 | Simulation Report | Individual work | No Presential | 02:30 | 20% | 5 / 10 | CE3<br>CE4<br>CG8<br>CE1<br>CG9 |
| 16 | Exam with the contents explained in the class | Written test | Face-to-face | 01:00 | 60% | 5 / 10 | |

### 7.1.2. Global examination

| Week | Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|---|---|---|---|---|---|---|---|
| 17 | Exam with the contents explained in the class | Written test | Face-to-face | 01:00 | 100% | 5 / 10 | CE3<br>CE4<br>CG8<br>CE1 |

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

| Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|---|---|---|---|---|---|---|
| Exam with the contents explained in the class | Written test | Face-to-face | 02:00 | 100% | 5 / 10 | CG8<br>CE1<br>CE3<br>CE4 |

### 7.2. Assessment criteria

The final mark will be formed by averaging the marks corresponding to the following items: practical questions and problems in Moodle (MOOD), report of simulation laboratory (SIM), and the exam (EX). The student passes the subjet if 0.60*EX+0.20*SIM+0.20*MOOD>5

**REMARK:** In case of need because of health and security reasons, the teaching and assessment activities will take place telematically.

## 8. Teaching resources

### 8.1. Teaching resources for the subject

| Name | Type | Notes |
|---|---|---|
| PRINCIPLES of the MANUFACTURING OF COMPOSITE MATERIALS by Suong V. Hoa, DESTECH | Bibliography | Reference book on manufacturing of composites |
| E. J. Barbero, Introduction to Composite Materials Design. CRC Press, 2011. | Bibliography | Reference book for design of composites materials |
| E. J. Barbero, Finite eElement Analysis of Composite Materials Using Abaqus, CRC Press, 2013. | Bibliography | Reference book on design of composites using finite elements |
| A 99 line topology optimization code written in Matlab | Bibliography | Simple code for topological optimization |

# 9. Other information

## 9.1. Other information about the subject

**REMARK:** In case of need because health and security reasons, the teaching and assessment activities will take place telematically. Laboratory classes will be also surpassed in that case and substituted by an intensification of Design and Simulation activities.