

# Course guide

## 240054 - 240054 - Continuum Mechanics

**Last modified:** 13/06/2023

**Unit in charge:** Barcelona School of Industrial Engineering  
**Teaching unit:** 737 - RMEE - Department of Strength of Materials and Structural Engineering.

**Degree:** BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Compulsory subject).

**Academic year:** 2023    **ECTS Credits:** 4.5    **Languages:** Catalan, Spanish

### LECTURER

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**Coordinating lecturer:** MIQUEL FERRER BALLESTER

**Others:**

Teoria:  
Ferrer Ballester, Miquel  
Bové Tous, Oriol  
Ayneto Gubert, Javier  
Ávila Haro, Jorge Arturo

Pràctiques de Laboratori:  
Fàbrega Freixes, Jordi  
Guilera Domingo, Jordi  
Soltanalipour, Milad  
Suñe Lago, Romà Enric

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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**Specific:**

11. Knowledge and capacities to apply fundamentals of materials' elasticity and resistance to the behaviour of real solids.

**Transversal:**

1. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
2. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.

### TEACHING METHODOLOGY

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Mixed theory/problems sessions: regular lectures and participatory self-assessment programmed activities to do during and out of class time. An undefined number of scoring in-class pop-up quizzes are also included.

Lab sessions: 2h sessions, experience-based learning. Groups of 15 people are organized into 3-student teams. Five sessions must be carried out: 1. Material testing, 2. Photo elasticity & DIC 3. Finite element simulation, session 4 consists of the draft presentation of the course project, and session 5 consists of the final presentation and report submission of the course project.

Course Project: Self-learning and cooperative. The team of three people formed in the lab groups perform a small project of free design of a piece or resisting element with the help of finite element software, optimize the piece, build a prototype and test it in the lab.

## LEARNING OBJECTIVES OF THE SUBJECT

At the end of the course, students should be able to:

- Analyze the fields of displacements, velocities and accelerations of the continuum, as well as their gradients, from the equations of continuum kinematics.
- Calculate and describe strains and strain rates of the continuum by tensorial algebra.
- Analyze the stress state and identify its main characteristics.
- Identify different constitutive models for continuum.
- Relate the stress and strain states for linear elastic continuum.
- Solve the elastic problem under different boundary conditions, calculating the stress and strain states at any point.
- Calculate the elastic safety factor in the continuum using the appropriate failure criterion. Identify the appropriate elastic failure criterion based on the nature of the material.
- Construct an appropriate numerical model using the finite element method for analysing linear elastic strains and stresses. Recognize and identify the appropriate boundary conditions based on a real situation of any object.
- Design a simple mechanical part or element and optimize its strength and stiffness.
- Analyze the results of finite element simulations.
- State the fundamental laws of continuum dynamics.

## STUDY LOAD

Type	Hours	Percentage
Guided activities	3,3	2.93
Hours large group	35,0	31.11
Hours small group	6,7	5.96
Self study	67,5	60.00

**Total learning time:** 112.5 h

## CONTENTS

### (ENG) - Continuum kinematics

#### Description:

Analysis of the displacements, velocities and accelerations fields, by both Lagrangian and Eulerian formulation. Deduction of the strain rate tensor and both finite or small strain tensor.

#### Specific objectives:

- Analyze the displacement, velocity and acceleration fields from continuum kinematics equations.
- Calculate and describe the continuum strain rate and strain using the tensorial algebra.

#### Related activities:

Programmed exercises 2.1 to 2.25, both in and outside the classroom.

#### Full-or-part-time: 29h

Theory classes: 11h

Self study : 18h



### (ENG) - Stress

**Description:**

Definition of the stress vector, intrinsic components of stress, stress tensor, equilibrium conditions, principal stresses and directions, Mohr circles, elastic failure criteria.

**Specific objectives:**

- Analyzing the stress state and identifying its main features.
- Representing any tensor magnitude by Mohr circles.
- Calculate the elastic safety factor of a mechanical component, using the appropriate failure criterion according to the nature of the material behaviour (brittle/ductile).

**Related activities:**

Programmed Exercises 3.1 to 3.12, both in and outside the classroom

**Full-or-part-time:** 32h

Theory classes: 10h

Laboratory classes: 4h

Self study : 18h

### (ENG) - Constitutive Models. Linear Elasticity

**Description:**

Constitutive equations, the principles of virtual work and power, generalized Hooke's law, the elastic problem, plane stress, plane strain, axisymmetry, the finite element method.

**Specific objectives:**

- Identify different continuum constitutive models.
- Relate strain and stress states of linear-elastic continuum.
- Solve the elastic problem in different boundary conditions, calculating the stress and strain states at any point.
- Build a suitable numerical model using the finite element method for the analysis of linear-elastic stresses and strains, recognize and identify the appropriate boundary conditions based on a real situation of any object.
- Design a simple mechanical part or element and optimize its stiffness and strength.
- Analyze the results of finite elements simulations.

**Related activities:**

Activities 4.1 to 4.4 and 5.1 to 12.5 for both within and outside the classroom.

Guided coursework.

Laboratory practices.

**Full-or-part-time:** 44h 30m

Theory classes: 15h

Laboratory classes: 4h

Self study : 25h 30m



### (ENG) - Continuum Dynamics

**Description:**

Control volume, Reynolds' theorem, mass, momentum, angular momentum conservation principles, the principles of virtual work and power.

**Specific objectives:**

- Stating the basic laws of the continuum dynamics.

**Related activities:**

6.1 to 6.3 activities inside the classroom.

**Full-or-part-time:** 7h

Theory classes: 1h

Self study : 6h

## ACTIVITIES

### IN-CLASS EXERCISES

**Description:**

Programmed activities to be solved during the session by teams of 2-3 students.

**Specific objectives:**

- Reversed learning: deducing theory concepts from an exercise before the formal theory lecture.
- Practicing concepts that have been already explained.
- Cooperative learning.
- Self-evaluation, co-evaluation.

**Material:**

The programmed activities are available on the digital campus or handed in at the moment.

**Delivery:**

The "Deliverable" activities are uploaded to the digital campus and solved by the professor on the board during the next class. Students correct their own exercises. The marks are not included in the global evaluation of the subject.

**Full-or-part-time:** 10h

Theory classes: 10h

### (ENG) ACTIVITATS PER ESCRIT FORA DE L'AULA



## LABORATORY SESSIONS

### Description:

Laboratory sessions to practice with experimental and numerical methods.

Practice 1: Materials testing

Práctica 2: Photoelasticity & Digital Image Correlation (DIC)

Práctica 3: The finite element method (FEM)

(Practices 4 and 5: see Coursework)

### Specific objectives:

- Experimental methods for material characterization
- Photoelasticity and digital image correlation for the visualization and experimental determination of stress/strain states
- Finite elements software for analysing stresses and strains of an elastic solid.
- Training in finite element simulation to ease the Coursework development.

### Material:

Laboratory of Elasticity and Strength of Materials (LERMA). Machinery for testing, specimens, tools, photoelastic bench, and ANSYS finite elements software. Session guides.

### Delivery:

Within one week after every lab session, each team of 3 students write a report containing the description, calculations and conclusions. The grade of this report signifies the 6% of the global subject grade.

**Full-or-part-time:** 10h

Laboratory classes: 10h

## (ENG) COURSE WORK

**Full-or-part-time:** 13h

Self study: 13h

## GRADING SYSTEM

$$NF = 0,2*NEP+0,3*NL+0,5 NEF$$

NF: FINAL MARK

NEP: MID-TERM EXAM MARK

NL: LABORATORY MARK (5 lab sessions)

NEF: FINAL EXAM MARK

The reevaluation exam will assess the entire subject content. The mark NREAVA will replace the marks NEP+NEF, so the final reevaluation mark will be as follow:  $NF = NL*0,3 + NREAVA*0,7$

## EXAMINATION RULES.

MID-TERM EXAM: Chapters 1 and 2 are evaluated except "Infinitesimal transformations". Only an A4 formula sheet with formulas, titles and drawings (no explanations), and a basic calculator (no programmable ones or with massive memory) can be used. It consists of 10 questions that can be either multiple-choice or open-response.

LABORATORY: Each team of 3 must write a report during sessions 1, 2 and 3, to be submitted within one week (3x0,2 points). Lab session 4 consists of the draft presentation of the course project (0,4 p). Lab session 5 consists of the presentation and final report submission of the course project and the prototype construction and testing in the laboratory (2 points). Mark NL is the sum of the 5 laboratory session marks.

FINAL EXAM: Consists of two or three 1h-duration parts, approximately, including either numerical or textual response questions, always focused on the conceptual comprehension of the subject. Only the official A4 formula sheet and a basic calculator (no programmable ones nor with massive memory) can be used.

## BIBLIOGRAPHY

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### Basic:

- Ayneto Gubert, X.; Ferrer Ballester, M. Mecánica del medio continuo en la ingeniería : teoría y problemas resueltos [on line]. Barcelona: Iniciativa Digital Politècnica, 2012 [Consultation: 09/09/2022]. Available on: <https://upcommons.upc.edu/handle/2099.3/36613>. ISBN 9788476539507.

### Complementary:

- Vieira Chaves, Eduardo Walter. Mecánica del medio continuo : Conceptos básicos.. Barcelona: CIMNE/UPC, 2007. ISBN 9788496736382.

- Oliver, J.; Agelet, C. Mecànica de medis continus per a enginyers [on line]. Barcelona: Edicions UPC, 2003 [Consultation: 13/09/2022]. Available on: <https://upcommons.upc.edu/handle/2117/97013>. ISBN 8483017199.

- Mase, G.T.; Mase, G.E. Continuum mechanics for engineers. 4th ed. Boca Raton: CRC Press, 2020. ISBN 9781482238686.

- Spencer, A.J.M. Continuum mechanics [on line]. Mineola: Dover Publications, 2004 [Consultation: 07/10/2020]. Available on: <https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=1894359>. ISBN 0486435946.

- Ortiz Berrocal, L. Elasticidad [on line]. 3a ed. Madrid: McGrawHill, cop. 1998 [Consultation: 18/10/2022]. Available on: [https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB\\_BooksVis?cod\\_primaria=1000187&codigo\\_libro=3965](https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=3965). ISBN 8448120469.

- Madenci, E.; Guven, I. The finite element method and applications in engineering using ANSYS [on line]. 2nd ed. New York: Springer, cop. 2015 [Consultation: 26/08/2022]. Available on: <https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-1-4899-7550-8>. ISBN 9781489975492.

## RESOURCES

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### Computer material:

- ANSYS Educational

### Hyperlink:

- <http://mmc.etseib.upc.edu/index.swf>