Course guide
240054 - 240054 - Continuum Mechanics

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: 2022 ECTS Credits: 4.5 Languages: Catalan, Spanish

LECTURER
Coordinating lecturer: MIQUEL FERRER BALLESTER
Others: Teoria:
MIQUEL FERRER BALLESTER
XAVIER AYNETO GUBERT
JOSEP Mª PONS POBLET
Pràctiques de Laboratori:
JORDI BONADA BO
JORDI FÀBREGA FREIXES
JORDI GUILERA DOMINGO
JOSUÉ LÓPEZ HERMOSO
ROMÀ SUÑÉ LAGO

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES
Specific:
11. Knowledge and capacities to apply fundaments 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
Mixed theory/problems sessions: regular lectures and participatory self-assessment programmed activities to do during and out of the
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 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 work: 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 continuum by tensorial algebra.
- Analyze the stress state and identify their 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 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 finite element method for analyzing linear elastic strains and stresses. Recognize and identifying the appropriate boundary conditions based on a real situation of any object.
- Analyze the results of finite elements simulations.
- State the basic laws of continuum dynamics.

STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours large group</td>
<td>35.0</td>
<td>31.11</td>
</tr>
<tr>
<td>Hours small group</td>
<td>6.7</td>
<td>5.96</td>
</tr>
<tr>
<td>Guided activities</td>
<td>3.3</td>
<td>2.93</td>
</tr>
<tr>
<td>Self study</td>
<td>67.5</td>
<td>60.00</td>
</tr>
</tbody>
</table>

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, axisymetry, 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
**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

---

**ACTIVITATS PER ESCRIT FORA DE L'AULA**
**ENG) PRACTIQUES DE LABORATORI**

**Description:**
Laboratory sessions to practice with experimental and numerical methods.
Practice 1: Materials testing  
Práctica 2: Photoelasticity  
Práctica 3: The finite element method  
(Practices 4 and 5: see Coursework)

**Specific objectives:**
- Experimental methods for material characterization  
- Photoelasticity for the visualization and experimental determination of stress/strain states  
- Finite elements software for the analysis of the 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 and specimens, tools and photoelastic bench, ANSYS finite elements software. Practices guides.

**Delivery:**
During the 2h lab sessions, each team of 3 students, write in-situ a report containing the description, calculations and conclusions. The reports are delivered at the end of each lab session. The grade of this report signifies the 3% of the global subject grade. On the other hand, practices 1 and 2 are also evaluated within the mid-term exam (40% of the exam, 4/10 test questions), i.e., 8% of the final subject grade. Therefore, the total weight is 11%.

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

---

**ENG) COURSE WORK**

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

---

**GRADING SYSTEM**

\[ NF = 0.2*NEP + 0.1*NEC + 0.2*NL + 0.5*NEF \]

NF: FINAL MARK  
NEP: MID-TERM EXAM MARK  
NEC: IN-CLASS EXERCISES MARK  
NL: LABORATORY MARK (5 lab sessions)  
NTR: COURSEWORK MARK  
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: \[ NF = NEC*0,1 + NL*0,2 + NREAVA*0,7 \]
EXAMINATION RULES.

MID-TERM EXAM: Chapters 1 and 2 as well as lab sessions 1 and 2 are evaluated. Only an A4 formulary with formulas, titles and drawings (no explanations) can be used as well as a basic calculator (no programmable ones or with massive memory).

POP-UP QUIZZES: short exercises to be solved individually during the theory/problems sessions. The number of exercises, frequency, content or calendar, is not defined in advance but defined on the go by the theory professor (pop quizzes).

LABORATORY: each team of 3 people must write a report during sessions 1, 2 and 3, to be submitted within one week (2x0,01 points). Lab session 4 consists of the draft presentation of the course project (0,02 p). Lab session 5 consists of the presentation and final report submitting of the course project, as well as the prototype construction and testing in the laboratory. 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 formulary can be used as well as a basic calculator (no programmable ones nor with massive memory).

BIBLIOGRAPHY

Basic:

Complementary:

RESOURCES

Computer material:
- ANSYS Educational

Hyperlink:
- http://mmc.etseib.upc.edu/index.swf