

## 34959 - CM - Computational Mechanics

Coordinating unit:	200 - FME - School of Mathematics and Statistics
Teaching unit:	749 - MAT - Department of Mathematics
Academic year:	2017
Degree:	MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits:	7,5
Teaching languages:	English

### Teaching staff

Coordinator:	JOSE JAVIER MUÑOZ ROMERO
Others:	Segon quadrimestre: JOSE JAVIER MUÑOZ ROMERO - A

### Prior skills

Basic knowledge of numerical methods  
Basic knowledge of partial differential equations

### Degree competences to which the subject contributes

Specific:

1. RESEARCH. Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. MODELLING. Formulate, analyse and validate mathematical models of practical problems by using the appropriate mathematical tools.
3. CALCULUS. Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
4. CRITICAL ASSESSMENT. Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

Transversal:

5. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
6. 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.
7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
8. 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.
9. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

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### Teaching methodology

Four elements will be combined:

- Theory classes, where the main concepts will be presented.
- Practical classes with Matlab code in the computer room, with emphasis on the computational aspects.
- Lists of short assignments.
- Course projects, with applications in biomechanics. To be presented orally at the end of the course.

Students will work on the assignments and course projects individually or in groups.

### Learning objectives of the subject

The main objective is to provide a general perspective of the broad field of computational mechanics, covering both the modelling and the computational aspects. A broad range of problems is addressed: solids, fluids and fluid-solid interaction; linear and nonlinear models; static and dynamic problems. Some emphasis is put on applications in biomechanical problems. By the end of the course, the students should:

- Be able to choose the appropriate type of model for a specific simulation
- Be familiar with the mathematical objects (mainly tensors) used in computational mechanics
- Be aware of the different level of complexity of various problems (e.g. linear vs. nonlinear, static vs. dynamic).

### Study load

Total learning time: 187h 30m	Hours large group:	60h	32.00%
	Self study:	127h 30m	68.00%

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### Content

<p>CONTINUUM MECHANICS</p>	<p>Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m</p>
<p>Description: Motivation. Definition of continuous media. Equation of motion: Eulerian and Lagrangian descriptions. Time derivatives. Strains: deformation gradient, Green and Euler-Almansi tensors; elongation and shear; small strains. Stresses: body and surface forces; Cauchy stress tensor. Balance equations: Reynolds transport theorem; mass balance; momentum balance. Constitutive equations. Applications.</p>	
<p>COMPUTATIONAL ELASTICITY</p>	<p>Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m</p>
<p>Description: Basic concepts and motivation. Elastic constitutive equation. Displacement formulation: Navier equations. Two-dimensional elasticity: plane stresses, plane strains and axisymmetry. Weak form of the elastic problem. Finite element discretisation. Computational aspects. Applications in engineering and biomechanics.</p>	
<p>COMPUTATIONAL DYNAMICS</p>	<p>Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m</p>
<p>Description: Weak form. Dynamic equation. Space discretisation (finite elements) and time discretisation. Solution methods: generalised eigen value problem and direct time integration. Euler, centred differences, HHT and Newmark methods. Stability, consistency and accuracy of numerical techniques in elastodynamics. Applications.</p>	

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<p>COMPUTATIONAL PLASTICITY AND VISCOELASTICITY</p>	<p>Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m</p>
<p>Description: Basic concepts and motivation. Non-linear problems. Geometrical and material non-linearity. One-dimensional plasticity: elastic and plastic strains; elastoplastic constitutive equation; hardening. Multi-dimensional plasticity: stress and strain invariants; yield surface; plastic flow. Numerical time-integration of the constitutive equation: elastic prediction and plastic correction; iterative methods for the plastic correction. Applications. Viscoelastic materials. Maxwell and Kelvin-Voigt one-dimensional models. Numerical solution. Extension to multiple dimensions.</p>	
<p>COMPUTATIONAL FLUID DYNAMICS</p>	<p>Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m</p>
<p>Description: Basic concepts and motivation. Rate-of-deformation and spin tensors. Constitutive equation for Newtonian fluids. Euler equations for inviscid flow. Navier-Stokes equations for viscous flow in strong form and in weak form. Reynolds number. Stokes flow and potential flow. Applications.</p>	
<p>COMPUTATIONAL METHODS FOR WAVE PROBLEMS</p>	<p>Learning time: 31h 15m Theory classes: 8h Practical classes: 2h Self study : 21h 15m</p>
<p>Description: Basic concepts and motivation. Acoustics: the wave equation. The scalar Helmholtz equation. Vibroacoustics: acoustic fluid-elastic solid interaction. Computational aspects. Applications. Electromagnetism: the Maxwell equations. Electrodynamics. The vectorial Helmholtz equation. Computational aspects. Applications.</p>	

### Qualification system

Final exam, assigned problems, and course project.

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### Bibliography

#### Basic:

Clough, Ray W.; Penzien, J. Dynamics of structures. 2nd ed. New York: McGraw-Hill, 1993. ISBN 0071132414.

Donea, Jean M.; Huerta, A. Finite element methods for flow problems. Chichester: John Wiley & Sons, 2003. ISBN 0471496669.

Ihlenburg, F. Finite element analysis of acoustic scattering [on line]. New York: Springer-Verlag, 1998 Available on: <<http://link.springer.com/book/10.1007%2Fb98828>>. ISBN 0387983198.

Mase, G. Thomas; Mase, George E. Continuum mechanics for engineers. 3rd ed. Boca Raton: CRC, 2010.

#### Complementary:

Bathe, Klaus-Jürgen. Finite element procedures. New Jersey: Prentice-Hall, 1996. ISBN 0133014584.

Bonet, Javier; Wood, R. D. Nonlinear continuum mechanics for finite element analysis. 2nd ed. Cambridge: Cambridge University Press, 2008. ISBN 9780521838702.

Holzappel, Gerhard A. Nonlinear solid mechanics : a continuum approach for engineering. Chichester: John Wiley & Sons, cop. 2000. ISBN 978-0-471-82319-3.

Marsden, Jerrold E.; Hughes, Thomas J. R. Mathematical foundations of elasticity. New York: Dover, 1994. ISBN 0486678652.

Simo, J. C.; Hughes, T. J. R. Computational inelasticity [on line]. New York: Springer-Verlag, 1998 Available on: <<http://link.springer.com/book/10.1007/b98904>>.

Taber, Larry A. Nonlinear theory of elasticity. Applications in Biomechanics [on line]. 2008. Singapore: World Scientific Publishing, 2004 [Consultation: 27/05/2015]. Available on: <<http://www.worldscientific.com/worldscibooks/10.1142/5452>>. ISBN 9812387358.

Zienkiewicz O. C.; Taylor, R. L. The finite element method [on line]. 6th ed. Oxford: Butterworth Heinemann, 2005 Available on: <<http://www.sciencedirect.com/science/book/9780750664318>>.