Course guide
295125 - 295II335 - Biomechanical Modelling

Last modified: 04/06/2026

Unit in charge: Barcelona East School of Engineering
Teaching unit: 712 - EM - Department of Mechanical Engineering.
702 - CEM - Department of Materials Science and Engineering.

Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN ADVANCED MATERIALS SCIENCE AND ENGINEERING (Syllabus 2021). (Optional subject).
MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Optional subject).
MASTER'S DEGREE IN ADVANCED BIOMEDICAL TECHNOLOGIES (Syllabus 2025). (Compulsory subject).

Academic year: 2026 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: GIL SERRANCOLÍ MASFERRER

Others: Primer quadrimestre:
DANIEL RODRÍGUEZ RIUS - Grup: T11, Grup: T12
DAVID SÁNCHEZ MOLINA - Grup: T11, Grup: T12
GIL SERRANCOLÍ MASFERRER - Grup: T11, Grup: T12

PRIOR SKILLS

- Use basic analytical mechanical methods to calculate forces and moments of a mechanical system.
- Solve differential equations.
- Use pressure/deformation calculation methods by finite elements of a simple system.
- Analyze basic signals.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMUEII-19. Develop translational applications with the aim of achieving a better understanding of physiological phenomena of clinical relevance and for the design of new applications in areas that have an impact on the health care of people. (Specific competence of the Healthcare and Biomedical Applications specialty)

Generical:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.
CGMUEII-05. To communicate hypotheses, procedures and results to specialized and non-specialized audiences in a clear and unambiguous way, both orally and through reports and diagrams, in the context of the development of technical solutions for problems of an interdisciplinary nature.

Transversal:
05 TEQ. 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.
06 URI. 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.
03 TLG. 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.

LEARNING RESULTS

Skills:
S1. Develop kinematic and dynamic analyses of biomechanical systems using the finite element method.
S10. Use common analysis tools in technological innovation to evaluate business opportunities and develop innovation proposals in the field of biomedical technologies.
S9. Plan the stages, tasks and activities involved in designing and developing biomedical devices and sensors or processing biomedical data.
S2. Appropriately use techniques for manufacturing, analysing and characterising biomaterials to choose them correctly and process them according to their properties and potential application.

Competences:
C3. Identify and analyse problems that require making autonomous, informed and reasoned decisions in order to act with social responsibility following ethical values and principles.
C1. Assume responsibilities in work teams in production management, as just another member or in a leadership role.
C5. Use scientific and technical information to respond to any demand for modification, innovation or improvement of devices, products and processes linked to biomedical engineering for new scientific or technological applications.
C7. Develop the ability to evaluate inequalities based on sex and gender to design solutions that resolve them.
C4. Use information resources effectively, manage the acquisition, structure, analysis and visualisation of data and information in the area of specialisation and critically assess the results.

TEACHING METHODOLOGY

This subject will combine theory sessions and one practical session per chapter. In theory sessions, the student will acquire the contents of each chapter, and in the practical sessions, he/she will be able to develop his/her skills using real biomechanical data.

LEARNING OBJECTIVES OF THE SUBJECT

• Understand the procedure to perform an inverse kinematics analysis from inertial sensor units.
• Learn the basic methods to calculate joint forces and moments of a biomechanical system during movement (macroscale analysis).
• Learn the most used constitutive models to model human tissues.
• Identify the boundary conditions of a microscale analysis (obtained from the macroscale analysis), mainly calculation of pressures and deformations using finite element methods. Familiarize with the main parameters of a constitutive tissue model.

STUDY LOAD

Type	Hours	Percentage
Self study	96,0	64.00
Hours small group	18,0	12.00
Hours large group	36,0	24.00

Total learning time: 150 h

CONTENTS

Chapter 1. Introduction

Description:
- Introduction to the subject (macroscale to microscale)
- Review of the macro and microscale modelling of human body

Specific objectives:
• Identify active and passive structures of the human body responsible of the movement to create the biomechanics system model.
• Identify the current motion capture systems that can be used to capture the human body movement.

Full-or-part-time: 2h
Theory classes: 2h

Chapter 2. Human body kinematics

Description:
2.1. Reminder of kinematics analysis
2.2. Human kinematics analysis with wearable devices
2.3. Case study: calculation of joint angles from IMUs (inertial measurement units)

Specific objectives:
• Calculate the joint angles by motion capture systems: optical cameras and inertial measurement units. Comprehend their differences, pros and cons.
• Learn how to perform an inverse kinematics analysis to a human movement.
• Learn to process data from an inertial measurement unit and extract the most relevant data.

Full-or-part-time: 23h
Theory classes: 4h
Laboratory classes: 2h
Self study : 17h

Chapter 3. Human body dynamics

Description:
3.1. Reminder Dynamics analysis.
3.2. Case study: calculation of dynamic joint moments.
3.3. Modelling of muscle forces.
3.4. Introduction to OpenSim (Inverse Kinematics, Inverse Dynamics, Static Optimization to estimate muscle forces).
3.5. Case study with OpenSim (analyze the difference in joint contact forces, depending on muscle-force sharing strategy).
3.6. Motion capture.

Specific objectives:
• The student will learn how to model the human body from a macro-scale point of view.
• Describe and perform inverse kinematics and dynamics analyses using the biomechanics open-source software OpenSim.
• Estimate muscle forces for a given movement.

Related activities:
Practical session 2. Motion capture and inverse kinematics and dynamics analyses.

Full-or-part-time: 28h
Theory classes: 7h
Laboratory classes: 4h
Self study : 17h

Chapter 4. Tissue Characterization and constitutive Models

Description:
4.1. Reminder of continuum mechanics
4.2. Kinematics of deformation and strain tensors
4.3. Forces in continuum mechanics and stress tensors
4.4. Equations of motion for deformable solids
4.5. Constitutive theory: examples of materials
4.6. Materials without memory: Linear and non-elasticity
4.7. Materials with memory: viscoelasticity and plasticity
4.8. Materials with memory: damage and degeneration parameters
4.9. Models for biological tissues (I): hard tissues
4.10. Models for biological tissues (II): soft tissues

Specific objectives:
• Comprehend how to apply the mechanical theories of continuous medium to develop a constitutive model for biological tissues.
• Learn the main phenomena of mechanical behaviour of tissues: anisotropy, viscoelasticity, fibres degeneration, etc.
• Learn how to design a set of specific experiments to adjust and calibrate parameter values of a specific constitutive model.

Related activities:
Practical session 4. Analysis of a flexion test with animal tissue.

Full-or-part-time: 55h
Theory classes: 15h
Laboratory classes: 6h
Self study : 34h

Chapter 5. FEM applied to biomechanics

Description:
5.1. Specificities of FEM applied to Biomechanics
5.2. Geometry and boundary conditions
5.3. FEM solver requirements for Biomechanical applications
5.4. Case study – Use of FEBio

Specific objectives:
Describe and perform a simulation by FEM of a hard tissue

Related activities:
Practical session 5 (use of FEBio in Biomechanics)

Full-or-part-time: 40h
Theory classes: 12h
Laboratory classes: 2h
Self study : 26h

GRADING SYSTEM

Any academic fraud, plagiarism or use or possession of unauthorised means in an assessment activity leads to a mark of zero (0) for the affected test or assignment. Furthermore, in accordance with the University's regulations, if disciplinary proceedings are initiated the subject is recorded as "Pending Assessment" until a decision is reached. These incidents are managed in accordance with the **Action Framework for Academic Integrity in Assessment at the UPC**.

Lab session reports (20%)
Group projects (20%)
Individual assignments (20%)
Mid-semester exam (15%)
Final exam of the subject (20%)

This subject does not include a reevaluation test.

EXAMINATION RULES.

The use of devices with communication capabilities is not allowed.
Attendance to all sessions is mandatory.

BIBLIOGRAPHY

Basic:

- Yamaguchi, Gary Tad. Dynamic modeling of musculoskeletal motion : a vectorized approach for biomechanical analysis in three dimensions [on line]. New York: Springer US, cop. 2006 [Consultation: 07/10/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=5750363. ISBN 9780387287508.
- Winter, David A. Biomechanics and motor control of human movement. 4th ed. Hoboken, New Jersey: John Wiley & Sons, cop. 2009. ISBN 9780470398180.
- McGinnis, Peter M. Biomechanics of sport and exercise. 2013. United Kingdom: Human Kinetics, 2013. ISBN 0736079661.
- Ronald L. Huston. Principles of Biomechanics. 2009. Boca Raton: CRC Press, Taylor & Francis, 2009. ISBN 9780849334948.
- Holzapfel, Gerhard A. Nonlinear solid mechanics : a continuum approach for engineering. Chichester: John Wiley & Sons, cop. 2000. ISBN 0471823198.
- Marsden, Jerrold E; Hugues, Thomas J.R. Mathematical foundations of elasticity. New York: Dover, 1994. ISBN 0-486-67865-2.
- Antman, S. S. Nonlinear Problems of Elasticity [on line]. 2nd ed. New York, NY: Springer, 2005 [Consultation: 07/10/2020]. Available on: http://dx.doi.org/10.1007/0-387-27649-1. ISBN 9780387276496.
- Uchida, Thomas K. Biomechanics of movement : the science of sports, robotics, and rehabilitation. Cambridge, MA: The MIT Press, 2021. ISBN 9780262044202.

RESOURCES

Computer material:

- OpenSim. Biomechanics software OpenSim. Link: https://simtk.org/frs/?group_id=91- FEBio. Biomechanics software of finite elements applied to biomechanics. Link: https://febio.org/