# Course guide
## 295125 - 295II335 - Biomechanics Modelling

**Last modified:** 27/05/2024

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| **Unit in charge:** | Barcelona East School of Engineering |
| **Teaching unit:** | 712 - EM - Department of Mechanical Engineering. |
| | 702 - CEM - Department of Materials Science and Engineering. |
| | 737 - RMEE - Department of Strength of Materials and Structural 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). |

**Academic year:** 2024    **ECTS Credits:** 6.0    **Languages:** English

## LECTURER

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| **Coordinating lecturer:** | Serrancolí Masferrer, Gil |
| **Others:** | Primer quadrimestre: |
| | DANIEL RODRÍGUEZ RIUS - Grup: T10 |
| | ANTONIO JOSÉ SÁNCHEZ EGEA - Grup: T10 |
| | DAVID SÁNCHEZ MOLINA - Grup: T10 |
| | GIL SERRANCOLÍ MASFERRER - Grup: T10 |

## 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.

## 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 | 108,0 | 72.00 |
| Hours small group | 21,0 | 14.00 |
| Hours large group | 21,0 | 14.00 |

**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:** 24h
Theory classes: 4h
Laboratory classes: 3h
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:** 48h
Theory classes: 11h
Laboratory classes: 3h
Self study : 34h

## 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:** 48h
Theory classes: 11h
Laboratory classes: 3h
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:** 24h
Theory classes: 4h
Laboratory classes: 3h
Self study : 17h

## GRADING SYSTEM

Lab session reports (25%)
Group projects (25%)
Individual assignments (30%)
Final exam of the subject (20%)

## 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/