COORDINATION PROCESS OF
LEARNING ACTIVITIES
PR/CL/001

INTERNATIONAL
CAMPUS OF
EXCELLENCE
POLITÉCNICA

ETSIT UPM E.T.S. de Ingenieros de
Telecomunicacion

ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000986 - Numerical Models For Tissue And Blood Flow Biomechanics

DEGREE PROGRAMME

09AU - Master Universitario En Ingenieria Biomedica

ACADEMIC YEAR & SEMESTER

2022/23 - Semester 2

Index

Learning guide

DRAFT VERSION

1. Description

1.1. Subject details

Name of the subject	93000986 - Numerical Models For Tissue And Blood Flow Biomechanics
No of credits	3 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 2
Tuition period	February-June
Tuition languages	English
Degree programme	09AU - Master Universitario en Ingenieria Biomedica
Centre	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Academic year	2022-23

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Pedro Navas Almodovar	1-15 (Caminos)	pedro.navas@upm.es	Sin horario. No fixed timetable
Jose Maria Goicolea Ruigomez (Subject coordinator)	T9-7 (Caminos)	jose.goicolea@upm.es	Sin horario. No fixed timetable
Javier Garcia Garcia	ETSIndustriales	javier.garciag@upm.es	Sin horario. No fixed timetable

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Sergio Blanco Ibañez	1-13 (Caminos)	sergio.blanco@upm.es	Sin horario. No fixed timetable

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

2.3. External faculty

Name and surname	Email	Institution
Javier Naranjo Pérez	javier.naranjo@externos.upm.es	Postdoc Margarita Salas en UPM

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- Vector calculus

- Computer programming

- Numerical methods

4. Skills and learning outcomes *

4.1. Skills to be learned

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CG-MIB01 - Resolver problemas e integrar conocimiento en temas nuevos o escasamente definidos y en entornos multidisciplinares del área de la Ingeniería Biomédica

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4.2. Learning outcomes

RA136 - Development and application of advanced numerical models for biomechanics of hard and soft human tissue

RA137 - Development and application of advanced numerical models for biomechanics of blood flow

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

OBJECTIVES

The object of this course is to develop know-how and skills, both at theoretical and at a practical level, in the field of biomechanics applied to medical problems, by the use of computational models. In a first part the human tissue, both hard and soft, will be studied. The mathematical and numerical models will be described and practice will be carried out in the computer with a nonlinear finite element program especially suited for biomedical applications. In a second part of the course the blood circulation (haemodynamics) will be studied, describing the relevant fluid mechanics models. The activity will also be focused on computational applications using finite volume CFD software.

All topics will include applications using advanced computational models (Finite Elements: FEBio, ABAQUS, CFD: Simvascular, Fluent).

COURSE PROGRAMME

Part 1. Finite Elements for hard and soft tissue biomechanics

1.1 *Introduction to nonlinear problems*

 1.2 *Concepts in nonlinear continuum biomechanics.* Nonlinear elasticity, viscoelasticity, plasticity, damage, failure criteria

1.3 *Formulation and solution of the discrete nonlinear equations*

1.4 *Adaptive remeshing.* Application to bone model

1.5 *Meshless methods* (SPH) and applications to biomechanics

1.6 *Patient-specific studies.* Segmentation from medical images, mesh generation.

Part 2. Computational Fluid Mechanics for Haemodynamics

2.1 *Haemodynamics.* Biofluid mechanics: fluid mechanical properties of the blood, rheology. Fundamental equations of

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the mechanics of fluids. Viscous flow in ducts: laminar and turbulent flow, pulsatile flow.

2.2 *General description of blood flow, modelling of the arterial and venous systems.* Study of blood flow in singularities (curves, bifurcations, etc). Vascular structure and its relation with the characteristics of blood flow.

2.3 *Flow in elastic ducts.* Windkessel model, wave propagation. Dynamics of bubbles and cavitation in blood flow. Mechanical similarity in arterial motion.

2.4 *Applications of computational fluid mechanics to blood flow.* Workshops: flow in bifurcations under steady flow conditions. Workshop: CFD study of left coronary arteries

5.2. Syllabus

1. Finite Elements for hard and soft tissue biomechanics

    1.1. Introduction to nonlinear problems

    1.2. Concepts in nonlinear continuum biomechanics. Nonlinear elasticity and damage

    1.3. Formulation and solution of the discrete nonlinear equations

    1.4. Adaptive remeshing. Application to bone model

    1.5. Meshless methods (SPH) and applications to biomechanics

    1.6. Patient-specific studies: segmentation from medical images, mesh generation.

2. Computational Fluid Mechanics for Haemodynamics

    2.1. Haemodynamics

    2.2. General description of blood flow, modelling of the arterial and venous systems

    2.3. Flow in elastic ducts

    2.4. Applications of computational fluid mechanics to blood flow

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Topic 1.1** Duration: 01:30 Lecture	**Topic 1.1 Assignment / exercise** Duration: 01:00 Laboratory assignments		
2	**Topic 1.2** Duration: 01:30 Lecture	**Topic 1.2 Assignment / exercise** Duration: 01:00 Laboratory assignments		
3	**Topic 1.3** Duration: 01:30 Lecture	**Topic 1.3 Assignment / exercise** Duration: 01:00 Laboratory assignments		
4	**Topic 1.4** Duration: 01:30 Lecture	**Topic 1.4 Assignment / exercise** Duration: 01:00 Laboratory assignments		
5	**Topic 1.5** Duration: 01:30 Lecture	**Topic 1.5 Assignment / exercise** Duration: 01:00 Laboratory assignments		
6	**Topic 1.6** Duration: 01:30 Lecture	**Topic 1.6 Assignment / exercise** Duration: 01:00 Laboratory assignments		
7	**Topic 2.1** Duration: 01:30 Lecture	**Topic 2.1 Assignment / exercise** Duration: 01:00 Laboratory assignments		
8	**Topic 2.2** Duration: 01:30 Lecture	**Topic 2.2 Assignment / exercise** Duration: 01:00 Laboratory assignments		
9	**Topic 2.3** Duration: 01:30 Lecture	**Topic 2.3 Assignment / exercise** Duration: 01:00 Laboratory assignments		
10	**Topic 2.4** Duration: 01:30 Lecture	**Topic 2.4 Assignment / exercise** Duration: 01:00 Laboratory assignments		
11				
12				
13				
14				
15				
16				
				Assistance to lectures and responses to short questionnaires, during each lecture Individual work Continuous assessment and final examination Presential Duration: 00:00 **Exercises and practical assignments, developed weekly for each lesson** Problem-solving test

17				Continuous assessment and final examination Presential Duration: 00:00 **Presentation of final course project** Individual work Continuous assessment and final examination Presential Duration: 03:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Assistance to lectures and responses to short questionnaires, during each lecture	Individual work	Face-to-face	00:00	15%	4 / 10	CB07 CG-MIB01
17	Exercises and practical assignments, developed weekly for each lesson	Problem-solving test	Face-to-face	00:00	45%	5 / 10	CB07 CG-MIB01
17	Presentation of final course project	Individual work	Face-to-face	03:00	40%	5 / 10	CB07 CG-MIB01

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Assistance to lectures and responses to short questionnaires, during each lecture	Individual work	Face-to-face	00:00	15%	4 / 10	CB07 CG-MIB01
17	Exercises and practical assignments, developed weekly for each lesson	Problem-solving test	Face-to-face	00:00	45%	5 / 10	CB07 CG-MIB01
17	Presentation of final course project	Individual work	Face-to-face	03:00	40%	5 / 10	CB07 CG-MIB01

7.1.3. Referred (re-sit) examination

No se ha definido la evaluación extraordinaria.

7.2. Assessment criteria

For passing the course it will be required to assist to the lectures, including short questionnaires, and complete the practical assignments / exercises, as well as the final course project.

The grades will be based on three criteria:

1. Attendance and participation in classes (15% of grades, with a minimum attendance of 70% of classes)
2. Assignments and exercises (45% of grades)

3. Final coursework: report, presentation and discussion (40% of grades)

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Slicer	Web resource	https://www.slicer.org
Meshlab	Web resource	http://www.meshlab.net
FEBio	Web resource	https://febio.org
ABAQUS	Web resource	Software de Elementos Finitos no lineal https://edu.3ds.com/en/software/abaqus-learning-edition
Simvascular	Web resource	http://simvascular.github.io
Paraview	Web resource	https://www.paraview.org/
Vascular Biomechanics	Bibliography	T.C. Gasser, 2021

9. Other information

9.1. Other information about the subject

This course contributes to the Sustainable Development Goals SDG 3 (Good health and well-being), SDG 4 (Quality education)