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

2020/21 - Semester 2

Index

Learning guide

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	2020-21

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Javier Garcia Garcia	ETSIndustriales	javier.garciag@upm.es	Tu - 12:00 - 14:00 Tu - 16:30 - 17:30
Sergio Blanco Ibañez	1-13 (ETSICCP)	sergio.blanco@upm.es	Tu - 12:00 - 14:00 Tu - 16:30 - 17:30
Jose Maria Goicolea Ruigomez (Subject coordinator)	T9-7	jose.goicolea@upm.es	Tu - 12:00 - 14:00 Tu - 16:30 - 17:30

Pedro Navas Almodovar	Lab Mat	pedro.navas@upm.es	M - 11:00 - 14:00 Tu - 11:00 - 14:00

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

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

- Computer programming

- Numerical methods

- Vector calculus

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

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 will be studied, describing the relevant fluid mechanics models. The activity will also be focused on computational applications using finite volume programs.

COURSE PROGRAMME

Part 1. Computational biomechanics of bone

- 1.1 Numerical simulation with the Finite Element Method in Biomechanics. Concepts, discretization and

analysis of results.

- 1.2 Physiology and mechanical properties of hard tissue.
- 1.3 Continuum biomechanics of hard tissue in small strain settings
- 1.4 Workshop 1.1 Finite element analysis of a bone
- 1.5 Workshop 1.2 Programming of a constitutive model

Part 2. Computational Biomechanics of soft tissue.

- 2.1 Continuum biomechanics for soft tissue in large strain settings
- 2.2 Nonlinear material models based on hyperelasticity
- 2.3 Workshop 2.1 Simulation of uniaxial extension of tissue with FEBio
- 2.3 Workshop 2.2 Processing of medical images and segmentation (Slicer), creation of Finite element model of organ (Meshlab), and simulation of loading using FEBio

Part 3. Computational biomechanics of blood flow

- 3.1 Biofluid mechanics: fluid mechanical properties of the blood, rheology. Fundamental equations of the mechanics of fluids. Viscous flow in ducts: laminar and turbulent flow, pulsatile flow.
- 3.2 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.
- 3.3 Flow in elastic ducts: Windkessel model, wave propagation. Dynamics of bubbles and cavitation in blood flow. Mechanical similarity in arterial motion.
- 3.4 Applications of computational fluid mechanics to blood flow.
- 3.5 Workshop 3.1: flow in bifurcations under steady flow conditions
- 3.6 Workshop 3.2: CFD study of left coronary arteries

5.2. Syllabus

1. Models for biomechanics of bone

   1.1. Numerical simulation with the Finite Element Method in Biomechanics. Concepts, discretization and analysis of results.

   1.2. Physiology and mechanical properties of hard tissue.

   1.3. Continuum biomechanics of hard tissue in small strain settings

   1.4. Workshop 1.1 Finite element analysis of a bone

   1.5. Workshop 1.2 Programming of a constitutive model

2. Models for biomechanics of soft tissue

   2.1. Continuum biomechanics for soft tissue in large strain settings

   2.2. Nonlinear material behaviour based on hyperelasticity

   2.3. Workshop 2.1 Simulation of uniaxial extension of tissue with FEBio

   2.4. Workshop 2.2 Processing of medical images and segmentation (Slicer), creation of Finite element model of organ (Meshlab), and simulation of loading using FEBio

3. Models for biomechanics of blood flow

   3.1. Biofluid mechanics: fluid mechanical properties of the blood, rheology. Fundamental equations of the mechanics of fluids. Viscous flow in ducts: laminar and turbulent flow, pulsatile flow

   3.2. 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.

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

   3.4. Applications of computational fluid mechanics to blood flow.

   3.5. Workshop 3.1: flow in bifurcations under steady flow conditions

   3.6. Workshop 3.2: CFD study of left coronary arteries

6. Schedule

6.1. Subject schedule*

Week	Face-to-face classroom activities	Face-to-face laboratory activities	Distant / On-line	Assessment activities
1	**Topic 1: Bone tissue mechanics** Duration: 01:30 Lecture		**Topic 1: Bone tissue mechanics** Duration: 01:30 Lecture	
2		**Topic 1. Bone tissue mechanics** Duration: 01:00 Laboratory assignments	**Topic 1. Bone tissue mechanics** Duration: 01:00 Laboratory assignments	
3	**Topic 1: Bone tissue mechanics** Duration: 01:30 Lecture		**Topic 1: Bone tissue mechanics** Duration: 01:30 Lecture	
4		**Topic 1. Bone tissue mechanics** Duration: 01:00 Laboratory assignments	**Topic 1. Bone tissue mechanics** Duration: 01:00 Laboratory assignments	**Project work topic 1** Individual work Continuous assessment Not Presential Duration: 15:00
5	**Topic 2. Soft tissue mechanics** Duration: 01:30 Lecture		**Topic 2. Soft tissue mechanics** Duration: 01:30 Lecture	
6		**Topic 2. Soft tissue mechanics** Duration: 01:00 Laboratory assignments	**Topic 2. Soft tissue mechanics** Duration: 01:00 Laboratory assignments	
7	**Topic 2. Soft tissue mechanics** Duration: 01:30 Lecture		**Topic 2. Soft tissue mechanics** Duration: 01:30 Lecture	
8		**Topic 2. Soft tissue mechanics** Duration: 01:00 Laboratory assignments	**Topic 2. Soft tissue mechanics** Duration: 01:00 Laboratory assignments	**Project work topic 2** Individual work Continuous assessment Not Presential Duration: 15:00
9	**Topic 3. Biomechanics of blood flow** Duration: 01:30 Lecture		**Topic 3. Biomechanics of blood flow** Duration: 01:30 Lecture	
10		**Topic 3. Biomechanics of blood flow** Duration: 01:00 Laboratory assignments	**Topic 3. Biomechanics of blood flow** Duration: 01:00 Laboratory assignments	
11	**Topic 3. Biomechanics of blood flow** Duration: 01:30 Lecture		**Topic 3. Biomechanics of blood flow** Duration: 01:30 Lecture	
12		**Topic 3. Biomechanics of blood flow** Duration: 01:00 Laboratory assignments	**Topic 3. Biomechanics of blood flow** Duration: 01:00 Laboratory assignments	

13	**Topic 3. Biomechanics of blood flow** Duration: 01:30 Lecture		**Topic 3. Biomechanics of blood flow** Duration: 01:30 Lecture	**Project work topic 3** Individual work Continuous assessment Not Presential Duration: 15:00
14				
15				
16				
17				**Presentation of assignments** Individual presentation Continuous assessment and final examination Presential Duration: 01:30 **Assignments** Individual work Final examination Not Presential Duration: 00:00

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. Continuous assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
4	Project work topic 1	Individual work	No Presential	15:00	25%	4 / 10	CB07
8	Project work topic 2	Individual work	No Presential	15:00	25%	4 / 10	CB07
13	Project work topic 3	Individual work	No Presential	15:00	25%	4 / 10	CB07
17	Presentation of assignments	Individual presentation	Face-to-face	01:30	25%	5 / 10	CB07

7.1.2. Final examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Presentation of assignments	Individual presentation	Face-to-face	01:30	25%	5 / 10	CB07
17	Assignments	Individual work	No Presential	00:00	75%	5 / 10	CB07

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Presentation of assignments	Individual presentation	Face-to-face	01:00	25%	5 / 10	CB07
Assignments	Individual presentation	Face-to-face	45:00	75%	5 / 10	CB07

7.2. Assessment criteria

Grading

Students will be graded through "continuous evaluation" by default. According to the "Normativa de Evaluación del Aprendizaje de la Universidad Politécnica de Madrid", students choosing to renounce to continuous evaluation must notify by email to the the professor responsible for the course 1 week before the final exam.

Grading will assess if students have acquired all the competences of the subject. Thus, grading through final exams will be carried out considering all the evaluation techniques used in continuous evaluation (EX, ET, TG, etc.), and will be performed in the exam period approved by "Junta de Escuela" for the current academic semester and year. Grading activities that assess learning outcomes that cannot be evaluated through a single exam can be carried out along the semester.

Extraordinary examination will be carried out exclusively by the final examination method.

- For the "ordinary" grading this will be based on the workshops and activities carried out during the course period. A minimum attendance to 70% of lectures and workshops will be required.
- Each of the three parts will include 2 workshops to which the students must attend, submit and defend the corresponding assignments. Each part will be graded with the weighed average of the corresponding workshops. A minimum of 3/10 will be required for each part.
- The overall grade of the course will be the average of the three parts, with a requirement of 5/10.
- For the extraordinary exam, for students who did not pass or did not attend the course workshops, they will be required to acquire the corresponding competences by themselves and submit and defend the corresponding assignments. The students must communicate with the course professors indicating their intention to attend this exam, and they will be informed of the assignments with 10 days time. As this examination includes a total of at least 6 workshop assignments the students will be required to present and defend them in morning and afternoon sessions.

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
Simvascular	Web resource	http://simvascular.github.io
Paraview	Web resource	https://www.paraview.org/