Biomechanics of continuum media II (fluids)

Academic Year: (2023 / 2024) **Review date: 19/12/2023 13:59:36**

Department assigned to the subject: Thermal and Fluids Engineering Department

Coordinating teacher: RODRIGUEZ RODRIGUEZ, FRANCISCO JAVIER

Type: Compulsory ECTS Credits : 6.0

Year : 2 Semester : 2

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Calculus I and II
Linear algebra
Differential equations
Biomechanics of continuum media I (solid mechanics)

LEARNING OUTCOMES

RA3: Be able to carry out conceptual designs for bioengineering applications according to their level of knowledge and understanding, working in a team. Design encompasses devices, processes, protocols, strategies, objects and specifications broader than strictly technical, including social awareness, health and safety, environmental and commercial considerations.
RA4: Be able to use appropriate methods to carry out studies and solve problems in the biomedical field, commensurate with their level of knowledge. Research involves conducting literature searches, designing and carrying out experimental practices, interpreting data, selecting the best approach and communicating knowledge, ideas and solutions within their field of study. May require consultation of databases, safety standards and procedures.
CB1: Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2: Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3: Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4: Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CG2: Ability to design, draft and develop scientific-technical projects in the field of biomedical engineering.
CG4: Ability to solve problems with initiative, decision-making, creativity, and to communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the biomedical engineer's activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG7: Drafting, representing and interpreting scientific-technical documentation.
CG11: Ability to solve problems characteristic of the theory of continuous media that may arise in engineering and biomedical sciences.
ECRT13: Ability to solve the characteristic problems of the theory of continuous media that may arise in engineering and biomedicine. Ability to apply knowledge of: solid mechanics, fluid mechanics and transport theory in continuous media of a biological nature.
CT1: Ability to communicate knowledge orally and in writing to both specialised and non-specialised audiences.
CT2: Ability to establish good interpersonal communication and to work in multidisciplinary and international teams.
CT3: Ability to organise and plan their work, making the right decisions based on the information available, gathering and interpreting relevant data in order to make judgements within their area of study.

OBJECTIVES

- The students must become familiar with the basic concepts of Fluid Mechanics: conservation laws, dimensional analysis, simplification of the general equations, etc.
- The students must become fluent in the usage of the mathematical tools commonly used in fluid mechanics: partial differential equations, usage of different coordinate systems, surface and volume integrals, complex variable, etc.

DESCRIPTION OF CONTENTS: PROGRAMME

1.- Introduction to fluid mechanics
1.1. Solids, liquids and gases
1.2. The continuum hypothesis
1.3. Density, velocity and internal energy
1.4. Local thermodynamic equilibrium. Equations of state.
2.- Kinematics of the fluid flow
2.1. Eulerian and Lagrangian descriptions
2.2. Uniform flow. Steady flow. Stagnation points.
2.3. Trajectories. Paths. Streamlines.
2.4. Substantial derivative. Acceleration.
2.5. Circulation and vorticity. Irrotational flow. Velocity potential.
2.6. Stream function
2.7. Strain-rate tensor
2.8. Convective flux. Reynolds transport theorem.
3.- Conservation laws in fluid mechanics
3.1. Continuity equation in integral form
3.2. Volume and surface forces
3.3. Stress tensor. Navier-Poisson law
3.4. Forces and moments on submerged bodies.
3.5. Momentum equation in integral form. Angular momentum equation.
3.6. Heat conduction vector. Energy equation in integral form.
4.- The Navier-Stokes equations
4.1. Navier-Stokes equations.
4.2. Initial and boundary conditions.
4.3. Bernoulli¿s equation
5.- Dimensional analysis
5.1. Dimensional analysis. The Pi theorem.
5.2. Applications
5.3. Nondimensionalization of the Navier-Stokes equations
5.4. Dimensionless numbers in fluid mechanics
6.- Viscous flows with applications to biomedical problems: circulatory flow, flow in airways, flow at the cell's scale
6.1. Unidirectional flows
6.2. The Stoke's problem
6.3. Quasi-one-directional flow
6.4. Applications to flows of interest in biology

LEARNING ACTIVITIES AND METHODOLOGY

Lectures: the main concepts of fluid mechanics are derived rigorously using physical and mathematical tools.

Seminars: the concepts derived in the lectures are used to solve problems. Also, new concepts are introduced through examples.

Homework: homeworks covering different areas of Fluid Mechanics are given to the students.

Lab sessions: the students will become familiar with the usage of numerical (computational) and experimental tools to investigate a canonical flow of biomedical interest.

ASSESSMENT SYSTEM

% end-of-term-examination/test:	40
% of continuous assessment (assigments, laboratory, practicals…):	60

1) Mid-term exam. It will cover approximately half the programme. If the grade is >= 5.0, the students do not need to take the exam on this part in the final (40% of the total grade)

% end-of-term-examination/test:	40
% of continuous assessment (assigments, laboratory, practicals…):	60

2) Final exam. It will cover the second half of the programme. Additionally, the students will have another opportunity to pass the exam of the first half. A minimum grade of 5.0 in the final is required to pass the course (40% of the total grade)
3) Homework (10%). Homework that the students are expected to complete.
4) LAB SESSION (4): Semi-analytical/Numerical simulation of the flow in an artery. Experimental characterization of the flow using Particle Image Velocimetry (PIV). The lab report will be 10% of the final grade.

BASIC BIBLIOGRAPHY

- G.I. Barenblatt Scaling, Cambridge University Press, 2003

- G.K. Batchelor An Introduction to Fluid Dynamics, Cambridge University Press, 2000

- Landau L.D., Lifshitz E.M. Fluid Mechanics, Pergamon Press, 1989

- Y.C. Fung Biomechanics: Mechanical Properties of Living Tissues, Second Edition, Springer; 2nd edition, 1993

- Y.C. Fung Biomechanics: Circulation, Springer; 2nd edition, 1996

- Y.C. Fung Biomechanics: Motion, Flow, Stress, and Growth, Springer, 1998