

Academic Year: ( 2022 / 2023 )

Review date: 20-12-2022

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)

## 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

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

<b>% end-of-term-examination:</b>	40
<b>% of continuous assessment (assignments, laboratory, practicals...):</b>	60

## 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