

Academic Year: (2021 / 2022)

Review date: 18-01-2022

Department assigned to the subject: Thermal and Fluids Engineering Department

Coordinating teacher: COENEN , WILFRIED ROMAIN STEFAN

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: two homework 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 ≥ 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.

% end-of-term-examination:	40
% of continuous assessment (assignments, laboratory, practicals...):	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