Fluid Mechanics I

Academic Year: (2023 / 2024) **Review date: 26-06-2023**

Department assigned to the subject: Thermal and Fluids Engineering Department

Coordinating teacher: FERNANDEZ TARRAZO, EDUARDO ANTONIO

Type: Compulsory ECTS Credits : 6.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Calculus I & II, Linear Algebra, Physics I & II

OBJECTIVES

Fundamental and applied knowledge of the laws that determine the fluid motion and their application to problems of interest in engineering: conservation laws for mass, momentum and energy (integral and differential form), dimensional analysis and simplifications of the general equations

DESCRIPTION OF CONTENTS: PROGRAMME

1. Introduction to Fluid Mechanics
  1.1. Solids, liquids and gases.
  1.2. The fluid as a continuum: Fluid particles.
  1.3. Density, velocity and internal energy.
  1.4. Local thermodynamic equilibrium.
  1.5. Equations of state.

2. Flow kinematics
  2.1 Coordinate systems
  2.2 Eulerian and Lagrangian descriptions. Uniform flow. Steady flow. Stagnation points.
  2.3 Trajectories. Paths. Fluid lines, Fluid surface, Fluid Volume.
  2.4 Streamlines, stream surface and stream tubes
  2.5 Material derivative. Acceleration
  2.6 Circulation and vorticity.
  2.7 Irrotational flow. Velocity Potential
  2.8 Stream function
  2.9 Local flow deformation. Strain-rate tensor
  2.10 Convective flow
  2.11 Reynolds transport theorem.

3. Conservation Laws
  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
  3.6 Angular momentum equation in integral form
  3.7 Heat conduction
  3.8 Energy equation in integral form. Different forms of the energy equation.

4. Conservation equations in differential form: Navier-Stokes equations.
  4.1 Continuity equation
  4.2 Momentum equation
  4.3 Energy equation. Internal energy and kinetic energy equations. Enthalpy and entropy equations.
  4.4 Initial and boundary conditions
  4.5 Bernoulli's equation.

5. Fluid statics
  5.1 Equilibrium equations
  5.2 Hydrostatics
  5.3 Forces and moments on submerged bodies. Archimedes' Principle.

5.4 The standard atmosphere

6. Dimensional analysis
   6.1 Dimensions of a physical magnitude
   6.2 Physical quantities with independent dimensions
   6.3 The Pi theorem
   6.4 Nondimensionalization of the Navier-Stokes equations; Dimensionless numbers in Fluid Mechanics
   6.5 Physical similarity. Partial similarity. Applications.

7. Viscous flow
   7.1 Uni-directional viscous flow in channels and pipes: Poiseuille and Couette flows
   7.2 Uni-directional unsteady flows: Rayleigh's problem and Stokes' flow
   7.3 Flows dominated by viscosity in ducts and channels of slowly varying cross section
   7.4 The pipe entrance region
   7.5 Introduction to hydrodynamic lubrication. The wedge effect.

LEARNING ACTIVITIES AND METHODOLOGY

The methodology will combine lecture classes for presentation of the fundamentals with problem solving sessions.
3 of the laboratory sessions, to take place in the computer room, are designed to provide a brief introduction to CFD, to enable students to use FLUENT for solving realistic flow problems.
One of the lab sessions will consist of hands-on work in the lab to take measures in a real problem and then use dimensional analysis.

ASSESSMENT SYSTEM

LAB (20%)
Part I exam (Midterm exam) (P1) (40%)
Part II exam (P2) (40%)
Course Grade CG = 0.20xLAB + 0.40xP1 + 040xP2

The continuous assessment allows the student to pass the course without final exam, provided a Course grade equal or greater than 5.0 is achieved and a minimum of 4.0 in each of the partial exams is achieved.

If the student fails to pass in the continuous assesment, the Final Grade (FG) is obtained after a Final Exam:

- Ordinary Final Exam (OFE)
  FG = 0.2xLAB + 0.1xP1 + 0.3xMAX(OFE1, P1) + 0.1xP2 + 0.3xMAX(OFE2,P2)
  The course is passed if FG >=5.0 and a minimum of 4.0 is obtained in each part of the final exam, EFO1 and EFO2

- Extraordinary Final Exam (EFE). There are no different parts, the exam is a whole.
  FG = MAX(0.1xLAB + 0.9xEFE, EFE)
  The course is passed if FG >= 5.0

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

BASIC BIBLIOGRAPHY

- A. Crespo Martínez Mecánica de Fluidos, Thompson, 2006
- D. J. Tritton Physical Fluid Dynamics, Oxford Science Publications, 1988
- F. M. White Fluid Mechanics, Mc-Graw Hill, 2015
- G. K. Batchelor An Introduction to Fluid Mechanics, Cambridge University Press, 1967
- L. D. Landau & E. M. Lifshitz Fluid Mechanics, Pergamon Press, 1987
- P. A. Lagerstrom Laminar Flow Theory, Princeton University Press, 1996

ADDITIONAL BIBLIOGRAPHY

- G.F. Carrier, C.E. Pearson. Ordinary Differential Equations. , SIAM (SIAM Classics in Applied Mathematics vol. 6). , 1991
- T. M. Apostol Calculus, John Wiley and Sons, 1969