UNICUSANO
ROME

Code: ING-IND/06 **Credits:** 9
Matter: Fluid Dynamics
Main language of instruction: Italian
Other language of instruction: English

Teaching Staff

Head instructor
Prof. Tiziano Pagliaroli – tiziano.pagliaroli@unicusano.it

Introduction

1. *Objective of the course:*

Understanding of the fundamentals of fluid dynamics.

Objectives

2. *Course Structure:*

At the start of course, prerequisite of the subject will be discussed. One/Two internal exams may be conducted.
Assignment based on course content will be given to the student for each unit/topic and will be evaluate.

Competencies:

• Understanding of the physical phenomena regulating by the Navier-Stokes equation. Knowledge of the main strategies for reducing aerodynamic drag. Knowledge of aerodynamic load increase strategies. Knowledge of intrusive and non-intrusive measurement techniques applied in wind tunnels. Knowledge of the concept of turbulence and its influence on aerodynamics forces.

Syllabus

3. *Programme of the course:*

Module 1 - Introduction
(2 video-recorded theory lessons requiring 7 hours – Week 1)
Fluid dynamics. Basics of continuum mechanics. Key quantities and parameters in fluid dynamics.

Equation of state for perfect gases. Thermodynamics overview.

Module 2 - Mathematics Review
(2 video-recorded theory lessons requiring 7 hours – Week 1)
Scalar and vector fields. Kronecker delta and Levi-Civita or Ricci symbol. Tensors. Scalar and vector product. Dyadic product. Double scalar product. Nabla operator. Useful theorems. Streamline and smoke line.

Module 3 - Kinematics of Fluid Particles
(1 video-recorded theory lesson requiring 3.5 hours – Week 1)
Eulerian and Lagrangian descriptions of motion. Velocity gradient and its decomposition. Conservation equations.

Module 4 - Conservation Equations
(6 video-recorded theory lessons requiring 21 hours – Weeks 1–2)
Reynolds transport theorem. Mass conservation equation. Momentum conservation equation (Navier-Stokes). Energy conservation equation. Non-dimensionalization of equations.

Module 5 - Exact Solutions
(1 video-recorded theory lesson requiring 3.5 hours – Week 2)
Exact solutions and Bernoulli's equation. Hagen-Poiseuille and Couette flow. Bernoulli's equation.

Module 6 - Vortices
(2 video-recorded theory lessons requiring 7 hours – Week 3)
Introduction. Circulation and vorticity. Kelvin's circulation theorem. Helmholtz's vortex theorems.

First Helmholtz theorem
Second Helmholtz theorem
Third Helmholtz theorem
Summary of Helmholtz theorems.
Vortices: Rotational vortex (rigid rotation), irrotational vortex, and Rankine vortex.
Module 7 - Boundary Layer
(4 video-recorded theory lessons requiring 14 hours – Week 4)
Conservation equations within the boundary layer. Conservation equations outside the boundary layer. Solution of boundary layer equations. Boundary layer over a flat plate (Blasius solution). Boundary layer separation.

Module 8 - Compressible Flows
(5 video-recorded theory lessons requiring 17.5 hours – Week 6)
Overview. One-dimensional steady models. Quasi-one-dimensional steady models. Normal shock and Rankine-Hugoniot relations. Non-isentropic flows.

Evaluation system and criteria

The assessments of course is based on the following criteria:

I) Final exam (95 %)
II) Homework (5 %)

The final exam consists of 3 open question.

Bibliography and resources

4. *Materials to consult:*

- Lecture notes
- Recorded and live lectures

5. *Recommended bibliography:*

- Fundamentals of Aerodynamics: John D Anderson