UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Course guide
220020 - MF - Fluid Mechanics

Last modified: 19/04/2023

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 729 - MF - Department of Fluid Mechanics.

Degree: BACHELOR'S DEGREE IN AEROSPACE TECHNOLOGY ENGINEERING (Syllabus 2010). (Compulsory subject).
BACHELOR'S DEGREE IN AEROSPACE VEHICLE ENGINEERING (Syllabus 2010). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 7.5 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: JOSEP M BERGADÀ GRANYÓ

Others: JOSEP M BERGADÀ GRANYÓ

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
4. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

TEACHING METHODOLOGY

The weekly lecturers are designed to present the theory accompanied by solved problems, yet many problems should be addressed by the students, this is directly related to Activity 1. Particular problems will need to be solved by the students at home and discussed in teams.
The application classes consist of problems mostly from the collection available in ATENEA. Some of these problems shall be introduced by the lecturer in class, but many others are meant to be solved by the students in teams and delivered as homework and in ATENEA forums. The student's resolutions will be accessible by all.
The practical classes consist of CFD simulations, the use of a personal laptop will be compulsory, alternatively computer classrooms can be employed. The simulations shall be performed in teams. The objective for the student is to be able to collect data, to process, analyze and draw conclusions, comparing the results with other reference, theoretical, numerical, or experimental results.

LEARNING OBJECTIVES OF THE SUBJECT

At the end of the course, the student should be able to:
Levels 1 and 2 (knowledge and compression)
- Define the basic properties of fluids
- Discuss the fundamental concepts of phenomena associated with fluids.

Level 3 (application)
- Students will be able to solve problems of Aeronautical Engineering related to the flow of Newtonian fluids
- Students will be able to solve problems of Aeronautical Engineering related to the compressible flow
- Use the theoretical, experimental and numerical tools appropriate to each problem.

STUDY LOAD

Type	Hours	Percentage
Self study	112,5	60.00
Hours large group	75,0	40.00

Total learning time: 187.5 h

CONTENTS

1 - Introduction and basic concepts

Description:
1.1 Definition of fluid
1.2 Continuum hypothesis
1.3 Properties of fluids

Related activities:
Theoretical classes
Activity 1
Activity 3 (control 1)
Activity 4 (first mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 4h
Theory classes: 2h
Self study : 2h

3 - Fluid Statics

Description:
2.1 Surface, mass and linear forces
2.2 Fundamental equation for Fluid Statics
2.3 The atmosphere
2.4 Fluid statics force on a surface
2.5 Archimedes' principle
2.6 Second Law of Archimedes
2.7 Stability

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 3 (control 1)
Activity 4 (first mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 10h 30m
Theory classes: 4h 30m
Self study : 6h

3 - Kinematics

Description:
3.1 Eulerian and Lagrangian description
3.2 Streamlines, pathlines and streaklines.
3.3 Substantial derivative
3.4 Circulation, flux and vorticity
3.5 Relative movement around a point

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 3 (control 1)
Activity 4 (first mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 3h 30m
Theory classes: 1h 30m
Self study : 2h

4 - Dynamics and General Equations

Description:
4.1 Conservatio equations
4.2 Reynolds' Transport Theorem
4.3 Differential and integral formulation
4.4 Conservation of mass
4.5 Conservation of momentum
4.6 Navier-Stokes Equations
4.7 Conservation of energy
4.8 Conservation of momentum of momentum
4.9. Bernuilli's Equation. Flowmeters.

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 3 (control 1)
Activity 4 (first mid-semester exam)
Activity 7 (Lab practice: Introduction to CFD)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 45h
Theory classes: 21h
Self study : 24h

5 - Dimensional analysis and theory of model

Description:
5.1 Bukingham's Pi Theorem
5.2 Basic dimensionless numbers
5.3 Nondimensionalization of equations
5.4 Similitude

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 3 (control 1)
Activity 4 (first mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 28h
Theory classes: 8h 30m
Self study : 19h 30m

6 - Viscous flows

Description:
6.1 Introduction to viscous flows
6.2 Equations an boundary conditions
6.3 Flow between two parallel plates
6.4 Continuity and Navier-Stokes equations in cylindrical coordinates
6.5 Hagen-Poiseuille flow
6.6 Flow between two concentric cylinders

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 5 (control 2)
Activity 6 (second mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 14h
Theory classes: 6h
Self study : 8h

7 - Turbulent flows

Description:
7.1 Introduction to Turbulence. Temporal Reynolds Averaging.
7.2 Physical interpretation of Reynolds' tensor
7.3 Law of the wall and turbulent boundary layer

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 5 (control 2)
Activity 6 (second mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 6h
Theory classes: 3h
Self study : 3h

8 - Boundary layer

Description:
8.1 Introduction to boundary layer
8.2 Laminar boundary layer. Prandtl's differential equation, Blasius' resolution
8.3 Von Karman momentum equation for the boundary layer
8.4 Turbulent boundary layer
8.5 Boundary layer with pressure gradient. Flow separation.

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 5 (control 2)
Activity 6 (second mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 10h 30m
Theory classes: 5h 30m
Self study : 5h

9 - Ideal and potential flows

Description:
9.1 Euler's equations
9.2 Stream function
9.3 Vorticity equation
9.4 Elementary potential flows
9.5 Circulation

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 6 (second mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 16h
Theory classes: 5h
Self study : 11h

10 - External Flow

Description:
10.1 Introduction to Aerdynamics
10.2 Friction and pressure drag forces
10.3 Aerodynamic coefficients
10.4 Airfoils

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activity 6 (second mid-semester exam)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 11h
Theory classes: 5h
Self study : 6h

11 - Compressible flow

Description:
11.1 Introduction to compressible flow. Review of thermodynamics
11.2 Speed of sound
11.3 Adiabatic flow
11.4 Sonic values
11.5 diffusers and injectors
11.6 Normal shock waves
11.7 Nozzles
11.8 Mach's conus
11.9 Oblique shock waves

Related activities:
Theretical and problem sessions
Activity 1
Activity 2
Activty 6 (second partial)

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 39h
Theory classes: 13h
Self study : 26h

ACTIVITIES

1 - THEORY AND PROBLEMS

Description:
Problems solved in class.

Specific objectives:
At the end of this activity the student should be able to:
- Find and analyze technical documentation in the biography and / or on Internet related to the proposed problems
- Work in teams and distribute tasks in order to efficiently solve problems.

Material:
Book of the subject and lecturer notes.
Collection of problems

Delivery:
Problems will be solved in class and discussed with the students.

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 165h 10m
Theory classes: 61h
Self study: 104h 10m

2 - CONTROL 1

Description:
Control exam solved by each student in classroom

Specific objectives:
At the end of this activity the student must be able to:
- Show the achievement of the specific objectives associated with contents 1, 2, 3 and first half of 4.

Material:
Formulae developed by each student.

Delivery:
The mark is part of the 10% of the global mark corresponding to controls grade.

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 1h 20m
Theory classes: 1h
Self study: 0h 20m

3 - FIRST MID-SEMESTER EXAM

Description:
Individual mid-semester exam

Specific objectives:
At the end of this activity the student should be able to:
- Show the achievement of the specific objectives associated with contents 1, 2, 3, 4 and 5

Material:
The students can bring everything they need.

Delivery:
The exam is the 30% of final course mark

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 3h 30m
Theory classes: 3h
Self study: 0h 30m

4 - CONTROL 2

Description:
Small exam performed in class individually.

Specific objectives:
At the end of this activity the student must be able to:
- Show the achievement of the specific objectives associated with contents 6, 7, 8 and first half of 8.

Material:
A sheet with handwritten formulae.

Delivery:
The mark is part of the 10% of the global mark corresponding to controls grade.

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 1h 20m
Theory classes: 1h
Self study: 0h 20m

5 - SECOND MID-SEMESTER EXAM

Description:
Individual mid-semester exam. It includes an activity for recovery of activity 4 (firs mid-semester exam)

Specific objectives:
At the end of this activity the student should be able to:
- Show the achievement of the specific objectives associated with content 6, 7, 8, 9, 10 and 11.

Material:
The students can bring all they believe it needed.

Delivery:
The exam is the 40% of the course global grade.

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 4h 30m
Theory classes: 4h
Self study: 0h 30m

6 - LAB PRACTICE. INTRODUCTION TO CFD

Description:
Lab practice with a very basic introduction to CFD tools that will be used in computer practices

Specific objectives:
At the end of this activity the student should be able to:
- Find information on the Internet, books, articles on numerical methods using CFD
- Describe in generic form what is a CFD program
- Perform a simulation with simple geometry, a laminar flow with standard contour conditions.
- Interpret the results obtained from a CFD simulation

Material:
CFD software
Desktop in computer classroom
Subject notes
Lab practices guide.

Delivery:
Report by teams.
The correct delivery of the report is part of the 10% of the overall course grade, corresponding to the laboratory grade

Related competencies :
CE16. GrETA/GrEVA - An adequate understanding of the following, as applied to engineering: concepts and laws that govern the processes of energy transfer, the movement of fluids, the mechanisms of heat transfer and phase transition, and their role in analysis of the main aerospace propulsion systems.

Full-or-part-time: 11h 40m
Theory classes: 5h
Self study: 6h 40m

GRADING SYSTEM

1st mid-semester exam, weight: 30%
2on mid-semester exam, weight: 40%
Class assignments, weight: 10%
Control tests, weight: 10%
CFD, weight: 10%

All students enrolled can return unsatisfactory results of the midterm exam on the day set in the final exam calendar. The redirection will consist of an optional additional exercise. The mark obtained in the exercise will be between 0 and 10 and will replace the mark of the partial exam exercise with the worst score, only in case it is higher (it can mean an improvement of up to 30%)

EXAMINATION RULES.

The control exams shall take about 1 hour. Students can use a self made formulae.

The mid-semester exams ones consist of:
- Two or three problems. They may include evaluation of theoretical concepts. Students shall use a self made formulae and calculator.

The exams have to be hand written.

Theoretical tasks must be presented periodically in ATENEA. They can be made by hand, scanned or photographed.
The problems must be presented in ATENEA, made with a word processor, with the format available in ATENEA, and always with pdf format.
The reports of the practices must be presented in ATENEA, made with a word processor, with the format available in ATENEA, and always with pdf format.

BIBLIOGRAPHY

Basic:
- Bergadà Granyó, J.M.; Mañas Gonzalez, A. Mecánica de fluidos: problemas con resolución numérica [on line]. Barcelona: Iniciativa Digital Politècnica, 2021 [Consultation: 20/09/2022]. Available on: http://hdl.handle.net/2117/344632. ISBN 9788498809268.
- Pnueli, David; Gutfinger, Chaim. Fluid mechanics. Cambridge ; New York: Cambridge University Press, 1992. ISBN 0521587972.
- Bergadà Granyó, Josep M. Mecánica de fluidos: breve introducción teórica con problemas resueltos [on line]. 3ª edición. Barcelona: Iniciativa Digital Politècnica, 2017 [Consultation: 28/10/2020]. Available on: http://hdl.handle.net/2099.3/36885. ISBN 9788498806885.
- Kundu, Pijush K.; Cohen, Ira M.; Dowling, David R. Fluid mechanics [on line]. 5th ed. Amsterdam [etc]: Elsevier, cop. 2012 [Consultation: 22/06/2022]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/book/9780123821003/fluid-mechanics. ISBN 9780123821003.
- White, Frank M. Mecánica de fluidos [on line]. 6ª ed. Madrid: McGraw-Hill, 2008 [Consultation: 20/09/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=4144. ISBN 9788448166038.
- Daily, James W. Dinámica de los fluidos : con aplicaciones en la ingeniería. México: Trillas, 1969.
- Gerhart, Philip M. [et al.]. Fundamentos de mecánica de fluidos. Argentina: Addison-Wesley Iberoamericana, 1995. ISBN 0201601052.
- Shames, Irving Herman. La mecánica de los fluidos. 3a ed. Santafé de Bogotá: McGraw-Hill, 1995. ISBN 9586002462.
- Sánchez Nieto, Manuel M. Mecánica de fluidos general. Cartagena: Universidad Politécnica de Cartagena. Escuela Técnica Superior de Ingeniería Industrial, 2007. ISBN 9788495781796.
- S. Fuertes Miquel, Vicente [et al.]. Problemas de mecánica de fluidos. Valencia: Universidad Politécnica de Valencia, 1999. ISBN 8477217378.
- López-Herrera Sánchez, José M. [et al.]. Mecánica de fluidos: problemas resueltos. Madrid: McGraw-Hill, 2005. ISBN 8448198891.
- Gordillo, J.M.; Riboux, G.; Fernández, J.M. Introducción a la mecánica de fluidos. Madrid: Paraninfo, 2017. ISBN 9788428339735.

Complementary:
- Bergadà Granyó, Josep M.; Kumar, Sushil. Fluid power, mathematical design of several components [on line]. New York: Nova Publishers, 2014 [Consultation: 02/11/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=3024242. ISBN 9781629483160.

- Anderson, John David. Modern compressible flow: with historical perspective. Boston: McGraw-Hill, 2003. ISBN 9780071241366.
- Bird, R. Byron; Stewart, Warren E.; Lightfoot, Edwin N. Fenómenos de transporte: un estudio sistemático de los fundamentos del transporte de materia, energía y cantidad de movimiento [on line]. Barcelona: Reverté, 1964 [Consultation: 27/05/2022]. Available on: https://web-p-ebscohost-com.recursos.biblioteca.upc.edu/ehost/ebookviewer/ebook?sid=4a2c59b1-f3ad-4d9d-bf20-c5d8483016dd%40redis&vid=0&format=EB. ISBN 9788429170504.
- Landau, L.D. [et al.]. Curso de física teórica, vol. 6, Mecánica de fluidos. Barcelona: Reverté, 1986. ISBN 9788429140873.
- Barrero Ripoll, Antonio [et al.]. Fundamentos y aplicaciones de la mecánica de fluidos. Madrid: McGraw-Hill, 2005. ISBN 8448198905.
- Batchelor, G.K. Introducción a la dinámica de fluidos. Madrid: Ministerio de Medio Ambiente. Dirección General del Instituto Nacional de Meteorología, 1997. ISBN 8483200155.
- Crespo, Antonio. Mecánica de fluidos. Madrid: Thomson, 2006. ISBN 8497322924.
- Liggett, James A. Fluid mechanics. New York: McGraw-Hill, 1994. ISBN 0070378053.
- Meseguer Ruiz, José. Aerodinámica básica. Madrid: Escuela Técnica Superior de Ingenieros Aeronáuticos, 2005. ISBN 8492111380.
- Taylor, Travis S. Introduction to rocket science and engineering. Boca Raton: CRC Press, 2009. ISBN 9781420075281.

RESOURCES

Hyperlink:
- www.efluids.com. Portal de recursos en internet sobre Mecánica de Fluids
- www.cfd-online.com. Portal sobre Computational Fluid Dynamics
- www.potto.org. Projecte per la publicació de material docent de forma oberta i gratuita. Llibre sobre Flux Compressible.

Other resources:
Notes and slides in Atenea