Course guides
220020 - MF - Fluid Mechanics

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: 2020  ECTS Credits: 7.5  Languages: Catalan, Spanish

LECTURER

Coordinating lecturer: JOSEP M BERGADÀ GRANYÓ

Others: MARC QUINTANA VALLMITJANA

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Hours small group</td>
<td>14,0</td>
<td>7.47</td>
</tr>
<tr>
<td>Self study</td>
<td>112,5</td>
<td>60.00</td>
</tr>
<tr>
<td>Hours large group</td>
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<td>25.07</td>
</tr>
<tr>
<td>Hours medium group</td>
<td>14,0</td>
<td>7.47</td>
</tr>
</tbody>
</table>

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 Conservation 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 Bernoulli's Equation, Flowmeters.

**Related activities:**
- Theoretical 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

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### 5 - Dimensional analysis and theory of model

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

**Related activities:**
- Theoretical 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 and 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:**
- Theroretical 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 Aerodynamics
- 10.2 Friction and pressure drag forces
- 10.3 Aerodynamic coefficients
- 10.4 Airfoils

**Related activities:**
- Thoretical 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:**
- Thoretical and problem sessions
- Activity 1
- Activity 2
- Activity 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 - SIMPLE EXERCISES PRESENTED IN THE THEORETICAL DOCUMENTATION OF THE SUBJECT

Description:
Simple exercises of application of the theoretical concepts presented in the documentation. They are made and weekly delivered on the digital campus.

Specific objectives:
At the end of this activity the student should be able to:
- Apply the concepts acquired in the theoretical sessions to solve simple problems

Material:
Notes of the subject in ATENEA

Delivery:
Exercises are weekly delivered. They can be handmade and scanned or photographed. The delivery is part of the 10% of the global mark corresponding to the class 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: 86h
Theory classes: 45h
Self study: 41h

2 - PROBLEMS

Description:
Problems solved in teams of 3 students. Problems are discussed 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:
Subject notes
Collection of problems

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: 53h 30m
Theory classes: 18h
Self study: 35h 30m
4 - CONTROL 1

Description:
Test type control solved by couples in the 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:
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: 5h
Theory classes: 1h
Self study: 4h

4 - 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:
Formulae used in controls

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: 11h
Theory classes: 3h
Self study: 8h
5 - CONTROL 2

Description:
Test type control solved by couples in the 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 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: 5h
Theory classes: 1h
Self study: 4h

6 - SECOND MID-SEMESTER EXAM

Description:
Individual mid-semester exam. It includes an activity for recovery of activity 4 (first 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:
Handwritten formulae used in controls

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: 11h
Theory classes: 3h
Self study: 8h
7 - 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: 8h
Theory classes: 4h
Self study: 4h

8 - PAPERS ANALYSIS

Description:
The student has to read an article or chapter of a book, in English, Spanish or Catalan, and make a small report/summary.

Specific objectives:
At the end of this activity the student should be able to:
- Extract from a scientific paper on Fluid Mechanics the most significant features
- Criticize and comment on a scientific article on Fluid Mechanics

Material:
Article

Delivery:
The assessment of the report is part of the 10% of the overall course mark, corresponding to the class 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: 8h
Self study: 8h
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:

Complementary:
RESOURCES

Hyperlink:
- www.cfd-online.com. Portal sobre Computational Fluid Dynamics
- www.potto.org. Projecte per la publicació de material docent de forma oberta i gratuïta. Llibre sobre Flux Compressible.

Other resources:
Notes and slides in Atenea