Course guide
300211 - MF - Fluid Mechanics

Last modified: 01/06/2023

Unit in charge: Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: BACHELOR'S DEGREE IN AEROSPACE SYSTEMS ENGINEERING (Syllabus 2015). (Compulsory subject).

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

LECTURER

Coordinating lecturer: Definits a la web de la universitat.

Others: Definits a la web de la universitat.

PRIOR SKILLS

· Computing ability in differential and integral vector calculus (double and triple integrals, gradient, divergence and rotational) and understanding vector theorems, contents of the subject Ampliación de Matemáticas of 1B.
· Computing ability in ordinary differential equations, content of the subject Algebra and Geometry of 1A and notions on equations in linear partial derivatives and on numerical approximation of derivatives, contents of the subject Ampliación de Matemáticas 2 of 2A
· Computing ability with the concepts and laws of mechanics and thermodynamics contained in the three physics subjects of semesters 1A, 1B and 2A.
· Programming in Python/Matlab/Octave language, content of the subject Informatics 1 of the 1B.

REQUIREMENTS

Prerequisites: Thermodynamics
Corequisites: Ampliación de Matemáticas 2

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE16. CE 16 AERO. Conocimiento adecuado y aplicado a la Ingeniería de: Los conceptos y las leyes que gobiernan los procesos de transferencia de energía, el movimiento de los fluidos, los mecanismos de transmisión de calor y el cambio de materia y su papel en el análisis de los principales sistemas de propulsión aeroespaciales. (CIN/308/2009, BOE 18.2.2009)
CE18. CE 18 AERO. Conocimiento adecuado y aplicado a la Ingeniería de: Los fundamentos de la mecánica de fluidos; los principios básicos del control y la automatización del vuelo; las principales características y propiedades físicas y mecánicas de los materiales. (CIN/308/2009, BOE 18.2.2009)
CE19. CE 19 AERO. Conocimiento aplicado de: la ciencia y tecnología de los materiales; mecánica y termodinámica; mecánica de fluidos; aerodinámica y mecánica del vuelo; sistemas de navegación y circulación aérea; tecnología aeroespacial; teoría de estructuras; transporte aéreo; economía y producción; proyectos; impacto ambiental. (CIN/308/2009, BOE 18.2.2009)
CE2. CE 2 AERO. Comprensión y dominio de los conceptos básicos sobre las leyes generales de la mecánica, termodinámica, campos y ondas y electromagnetismo y su aplicación para la resolución de problemas propios de la ingeniería. (CIN/308/2009, BOE 18.2.2009)

Generical:
CG1. (ENG) CG1 - Capacidad para el diseño, desarrollo y gestión en el ámbito de la ingeniería aeronáutica que tengan por objeto, de acuerdo con los conocimientos adquiridos, los vehículos aeroespaciales, los sistemas de propulsión aeroespacial, los materiales aeroespaciales, las infraestructuras aeroportuarias, las infraestructuras de aeronavegación y cualquier sistema de gestión del espacio, del trafico y del transporte aéreo.
CG2. (ENG) CG2 - Planificación, redacción, dirección y gestión de proyectos, cálculo y fabricación en el ámbito de la ingeniería aeronáutica que tengan por objeto, de acuerdo con los conocimientos adquiridos, los vehículos aeroespaciales, los sistemas de propulsión aeroespacial, los materiales aeroespaciales, las infraestructuras aeroportuarias, las infraestructuras de aeronavegación y cualquier sistema de gestión del espacio, del trafico y del transporte aéreo.

Transversal:
CT6. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.
CT3. EFFICIENT ORAL AND WRITTEN COMMUNICATION - Level 2. Using strategies for preparing and giving oral presentations. Writing texts and documents whose content is coherent, well structured and free of spelling and grammatical errors.
CT7. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
CT2. SUSTAINABILITY AND SOCIAL COMMITMENT - Level 2. Applying sustainability criteria and professional codes of conduct in the design and assessment of technological solutions.
CT5. EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 1. Identifying information needs. Using collections, premises and services that are available for designing and executing simple searches that are suited to the topic.
CT4. TEAMWORK - Level 1. Working in a team and making positive contributions once the aims and group and individual responsibilities have been defined. Reaching joint decisions on the strategy to be followed.

Basic:
CB1. (ENG) CB1 - Que los estudiantes hayan demostrado poseer y comprender conocimientos en un área de estudio que parte de la base de la
educación secundaria general, y se suele encontrar a un nivel que, si bien se apoya en libros de texto avanzados, incluye también algunos aspectos que implican conocimientos procedentes de la vanguardia de su campo de estudio
CB2. (ENG) CB2 - Que los estudiantes sepan aplicar sus conocimientos a su trabajo o vocación de una forma profesional y posean las competencias que suelen demostrarse por medio de la elaboración y defensa de argumentos y la resolución de problemas dentro de su área de estudio
CB4. (ENG) CB4 - Que los estudiantes puedan transmitir información, ideas, problemas y soluciones a un público tanto especializado como no especializado
CB5. (ENG) CB5 - Que los estudiantes hayan desarrollado aquellas habilidades de aprendizaje necesarias para emprender estudios posteriores con un alto grado de autonomíA

TEACHING METHODOLOGY

The course will be taught by combining master classes (theory group sessions), problem-directed activities that students will have previously solved at home, and a small group project on numerical methods in fluid mechanics problems, which students will do primarily outside from the classroom.

Theory classes will mainly follow the expository model, in which the teacher will introduce the basic concepts and laws of fluid mechanics, with the support of the blackboard and/or slides. The problem-directed classes will allow to consolidate the knowledge of these concepts and laws, and to use them to solve problems. With a week in advance, the list of problems to be solved by the students outside the classroom will be distributed. The problems will be discussed later on in the corresponding session and some of these problems will be solved on the blackboard by the students and/or teachers. The project will be done in small groups and mainly outside the classroom. Towards the end of the semester the groups should present the project with slide support.

The Atenea Digital Campus will be used routinely for the exchange of documentation between students and teachers and to keep the evaluation process updated. The texts and videos related to the syllabus that are necessary to guide the learning of the students and the problem collection will also be uploaded.

The oral and written expression will be covered explicitly in the AD problem sessions (discussion of the methods used and problem solving on the blackboard) and in the project. There will also be implicit work on the exams, since students will be asked to justify the resolution of the problems and answer theoretical questions. The third language (English) will be worked mainly on the project, since everything delivered must be written in English and the oral presentation might also be done in English. In addition, one of the two basic books, some of the contents of Athena and the problem formulation of the collection will be in English. Autonomous learning will be guided by texts with theoretical concepts of the subject and/or explanatory videos. Students should also individually solve the collection of problems at home, learning autonomously to apply theoretical knowledge to solve more specific problems. The project will also be an autonomous learning work tool, since students must acquire knowledge beyond that explained in theory classes and carry out much of the project autonomously. These three generic competences will be evaluated in the different evaluation activities in which they are involved (see detailed description of AV1-5).

LEARNING OBJECTIVES OF THE SUBJECT

Upon completion of the Fluid Mechanics course, the student must be able to:

· Define the variables and fundamental concepts of fluid mechanics: pressure, density, velocity, internal energy, viscosity, stress tensor, Lagrangian and Eulerian descriptions, Stokes derivative, streamline, pathline, circulation, vorticity, heat flux, sound speed, shock wave, boundary layer, turbulence, adiabatic flow, isentropic flow, characteristic dimensionless numbers (Reynolds, Mach, etc.), etc.

· Explain the meaning and implications of the conservation laws that govern fluid dynamics, both in integral and differential form: mass conservation, momentum balance equation and energy balance equation.

· Identify the different types of fluids (incompressible / compressible, non-viscous / viscous, subsonic / supersonic, irrotational / rotational) and the specific magnitudes and laws that allow to describe their movement.

· Deduce qualitative and quantitative conclusions from the specific magnitudes and laws that govern the movement of different types of fluid.

· Use the concepts and laws of conservation acquired and the appropriate mathematical tools to solve problems of a certain level of complexity in fluid mechanics, placing special emphasis on practical problems of aerodynamics.

· Communicate clearly and effectively orally and in writing to justify scientific reasoning with qualitative and quantitative arguments.

· Acquire knowledge autonomously, using the sources of information and guidelines indicated and identifying learning deficiencies.

· Read and interpret technical documents written in English related to Fluid Mechanics and know how to correctly use oral and written English in the context of the project of the subject.

· Apply criteria and propose alternatives that eliminate the causes of gender discrimination in a given context or situation.

STUDY LOAD

Type	Hours	Percentage
Hours large group	48,0	25.60
Self study	105,0	56.00
Guided activities	34,5	18.40

Total learning time: 187.5 h

CONTENTS

INTRODUCTION TO FLUID MECHANICS

Description:
· Presentation. Fluid concept. Definition of fluid as a continuous medium.
· Dimensions and unit systems. Fundamental variables: density, pressure, velocity and temperature.
· Thermodynamic variables: internal energy and enthalpy. Viscosity and shear stresses.
· Classification of the types of flows according to the physical properties of the fluid (viscosity and density), and according to the characteristics of the movement.
· Fluid statics. Hydrostatic balance principle. The standard atmosphere. Force on submerged surfaces. Force on submerged bodies.

Related activities:
· AV1: Problem exam of topics 1 and 2.
· AV2: Solving problems of the collection outside the classroom by the student. Exposure of problems in AD sessions by teachers and/or students. Collective discussion on the methods used and the results obtained.
· AV4: Mid-term exam.
· AV5: Final exam.

Full-or-part-time: 18h
Theory classes: 6h
Guided activities: 4h
Self study : 8h

FLUID KINEMATICS

Description:
· Modes of study of movement: Euler and Lagrange. Stokes or material derivative.
· Trajectories and streamlines.
· Volume and mass fluxes and mean velocity. Velocity divergence. Stream function.
· Rotation and deformation of a fluid particle. Vorticity and irrotational flow. Circulation. Velocity potential.

Related activities:
· AV1: Problem exam of topics 1 and 2 (1 h of AD assigned to this topic).
· AV2: Solving problems of the collection outside the classroom by the student. Exposure of problems in AD sessions by teachers and/or students. Collective discussion on the methods used and the results obtained.
· AV4: Mid-term exam.
· AV5: Final exam.

Full-or-part-time: 25h
Theory classes: 6h
Guided activities: 5h
Self study : 14h

FLUID DYNAMICS: EQUATIONS IN INTEGRAL FORM

Description:
· Fluid models. Quasi-one-dimensional flow. Reynolds transport theorem.
· Mass conservation equation.
· Linear momentum balance equation. Surface forces and volume forces. Bernoulli equation.
· Energy balance equation. Internal energy and enthalpy. Stationary flow in ducts.

Related activities:
· AV2: Solving problems of the collection outside the classroom by the student. Exposure of problems in AD sessions by teachers and/or students. Collective discussion on the methods used and the results obtained.
· AV4: Mid-term exam.
· AV5: Final exam.

Full-or-part-time: 28h
Theory classes: 7h
Guided activities: 4h
Self study : 17h

FLUID DYNAMICS: EQUATIONS IN DIFFERENTIAL FORM

Description:
· Mass conservation equation in differential form.
· Linear momentum balance equation in differential form. Shear stresses and viscosity. Euler's equations for non-viscous flow. Navier-Stokes equations for Newtonian viscous flow.
· Flow in laminar regime. Couette and Poiseuille flow. Movement between plates. Axisymmetric movement within cylindrical ducts.
· Energy balance equation in differential form. Heat flux.
· Initial and boundary conditions.
· Dimensional analysis. Non-dimensionalization of equations. Similarity concept.
· Notions of numerical methods in fluid mechanics.

Related activities:
· AV2: Solving problems of the collection outside the classroom by the student. Exposure of problems in AD sessions by teachers and/or students. Collective discussion on the methods used and the results obtained.
· AV3: Problem exam of topics 4 and 5.
· AV5: Final exam.

Full-or-part-time: 45h
Theory classes: 11h
Guided activities: 6h
Self study : 28h

INCOMPRESSIBLE, INVISCID FLOWS

Description:
· Applications of the Bernoulli equation in aerodynamics. Quasi-one-dimensional incompressible flow: low-speed wind tunnel and Pitot tube. Pressure coefficient.
. Laplace equation for potential flows and boundary conditions.
· Two-dimensional elementary potential flows: uniform, source, vortex and doublet. Combinations of elementary flows. Potential flow around cylinders and Magnus effect.

Related activities:
· AV2: Solving problems of the collection outside the classroom by the student. Exposure of problems in AD sessions by teachers and/or students. Collective discussion on the methods used and the results obtained.
· AV3: Problem exam of topics 4 and 5 (1 h of AD assigned to this topic)..
· AV5: Final exam.

Full-or-part-time: 32h
Theory classes: 7h
Guided activities: 3h
Self study : 22h

COMPRESSIBLE, INVISCID FLOWS

Description:
· Compressibility of a fluid. Energy equation for compressible inviscid flow. Stagnation conditions.
· Speed of sound. Mach number. Alternative versions of the energy equation. Sonic conditions.
· Normal shock waves. Oblique shock waves.
· Expansion of supersonic flow. Prandtl-Meyer expansion.
· Compressible flow movement in nozzles or ducts with slowly variable section.

Related activities:
· AV2: Solving problems of the collection outside the classroom by the student. Exposure of problems in AD sessions by teachers and/or students. Collective discussion on the methods used and the results obtained.
· AV5: Final exam.

Full-or-part-time: 39h 30m
Theory classes: 10h
Guided activities: 6h
Self study : 23h 30m

ACTIVITIES

AV1: PROBLEM TEST 1

Description:
During an AD session, there will be an individual control of problems in topics 1 and 2.

Specific objectives:
Validate the knowledge gained on topics 1 and 2, by teachers and students. Develop the ability to communicate clearly and effectively in writing, by justifying problem solving.

Material:
Problem formulation on paper, calculator and formula list.

Delivery:
The individually resolved control will be handed in to be assessed.

Full-or-part-time: 7h
Guided activities: 1h
Self study: 6h

AV2: SUPERVISED ACTIVITIES OF PROBLEM SOLVING

Description:
In AD sessions, we will work on the problems of the corresponding topic collection, which the students must previously solve at home. There will be a presentation of some of the problems on the blackboard by the teachers and/or students. The methods used and the results obtained will be discussed collectively.

Specific objectives:
Consolidate the knowledge gained in theory classes. Develop the ability to solve problems in fluid mechanics. Acquire autonomously the lacking knowledge to be able to solve the problems of the collection at home. Develop the ability to communicate orally clearly and effectively.

Material:
Collection with the formulation of the proposed problems (including the solutions at the end), calculator and formula list.

Full-or-part-time: 81h
Guided activities: 27h
Self study: 54h

AV3: PROBLEM TEST 2

Description:
During an AD session, there will be an individual control of problems in topics 4 and 5

Specific objectives:
Validate the knowledge gained on topics 4 and 5, by teachers and students. Develop the ability to communicate clearly and effectively in writing, by justifying problem solving.

Material:
Problem formulation on paper, calculator and formula list.

Delivery:
The individually resolved control will be handed in to be assessed.

Full-or-part-time: 7h
Guided activities: 1h
Self study: 6h

AV4: MID-TERM EXAM

Description:
During the week of half-term exams there will be an individual exam of theory and problems of the contents covered so far.

Specific objectives:
Verify the knowledge gained about the contents included, by teachers and students. Develop the ability to communicate clearly and effectively in writing, by justifying problem solving and answering theoretical questions.

Material:
Formulation of the problems and questions on paper, calculator and formula list.

Delivery:
The individually resolved exam will be handed in to be assessed.

Full-or-part-time: 10h 30m
Guided activities: 1h 30m
Self study: 9h

AV5: FINAL EXAM

Description:
During the week of final exams there will be an individual exam of theory and problems of all the contents of the subject.

Specific objectives:
Check the knowledge gained about the contents of the subject, by teachers and students. Develop the ability to communicate clearly and effectively in writing, by justifying problem solving and answering theoretical questions.

Material:
Formulation of the problems and questions on paper, calculator and formula list.

Delivery:
The individually resolved exam will be handed in to be assessed.

Full-or-part-time: 13h 30m
Guided activities: 2h
Self study: 11h 30m

GRADING SYSTEM

The evaluation criteria defined in the infoweb of the course will be applied.

EXAMINATION RULES.

All proposed assessment activities are mandatory. An exam, control, deliverable or project not submitted will be scored with a grade of zero. Examinations and controls will be performed individually. The project will be carried out in small groups.

BIBLIOGRAPHY

Basic:

- Anderson, John David. Fundamentals of aerodynamics [on line]. 5th ed. New York: McGraw-Hill, cop. 2011 [Consultation: 10/10/2023]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=5662650. ISBN 9780073398105.
- Anderson, John D; Bowden, Mary L. Introduction to flight [recurs electrònic] [on line]. Ninth edition. New York, 2022 [Consultation: 22/11/2023]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=6456151. ISBN 9781264363407.
- White, Frank M. Fluid mechanics [on line]. Eighth edition. Ney Work, NY: McGraw-Hill Education, [2016] [Consultation: 26/07/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=6327616. ISBN 9780073398273.
- White, Frank M. Mecánica de fluidos [on line]. 6ª ed. Madrid [etc.]: McGraw-Hill, 2008 [Consultation: 26/07/2022]. Available on: https://www-ingebook-com.recursos.biblioteca.upc.edu/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=4144. ISBN 9788448166038.

Complementary:

- Anderson, John David. Computational fluid dynamics. New York [etc.]: McGraw-Hill, 1995. ISBN 0070016852.
- Anderson, John David. Introduction to flight. 6th ed. Boston [etc.]: McGraw-Hill, 2008. ISBN 9780073529394.
- Batchelor, G.K. An introduction to fluid dynamics. Cambridge: Cambridge University Press, 2000. ISBN 0521663962.