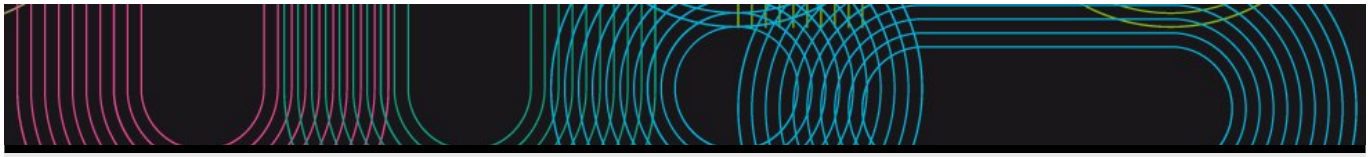

IDENTIFYING DATA				
Fluid mechanics II and CFD				
Subject	Fluid mechanics II and CFD			
Code	O07G410V01922			
Study programme	Grado en Ingeniería Aeroespacial			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	9	Optional	3rd	1st
Teaching language	#EnglishFriendly Spanish Galician			
Department				
Coordinator	Rodríguez Pérez, Luis Suárez Porto, Eduardo			
Lecturers	Rodríguez Pérez, Luis Suárez Porto, Eduardo			
E-mail	lurodriguez@uvigo.es suarez@uvigo.es			
Web	http://aero.uvigo.es			
General description	Knowledge, understanding and application of concepts and techniques of Fluid Mechanics in Aerospace Engineering. Part of the subject is presented as an introduction to computational fluid dynamics which, starting from a knowledge of fluid conservation equations (already acquired by students in previous subjects) allows the student to carry out simple simulations involving a fluid. as a means of work. English Friendly subject: International students may request from the teachers: a) resources and bibliographic references in English, b) tutoring sessions in English, c) exams and assessments in English.			

Training and Learning Results	
Code	
A2	That the students know how to apply their knowledge to their work or vocation in a professional way and that they possess the competences that are usually demonstrated through the elaboration and defense of arguments and the resolution of problems within their area of study
A3	That the students have the capability to gather and interpret relevant data (usually within their area of study) to issue judgments that include a reflection on relevant social, scientific or ethical issues
A5	That the students develop those learning capabilities necessary to undertake further studies with a high degree of autonomy.
C16	Appropriate knowledge applied to engineering: Concepts and laws that govern the processes of transfer of energy, the movement of fluids, the mechanisms of transmission of heat and the interchange of matter and its role in the analysis of the main propulsion systems in aerospace engineering.
C18	Appropriate knowledge applied to the engineering: foundations of fluid mechanics; basic principles of control and automation of flight; main characteristics and physical and mechanical properties of the materials.
C19	Applied knowledge of: science and technology of materials; mechanics and thermodynamics; fluid mechanics; aerodynamics and flight mechanics; navigation and air traffic systems; aerospace technology; theory of structures; airborne transportation; economy and production; projects; environmental impact.
C20	Appropriate knowledge applied to engineering: mechanics of fracture of the continuous media and their dynamic behavior, fatigue of structural instability and aeroelasticity.
C22	Appropriate knowledge applied to engineering: foundations of fluid mechanics that describe the flow in all regimes, to determine the distributions of pressures and forces on an aircraft.
C25	Appropriate knowledge applied to engineering: methods of design calculations and aeronautical projects; use of aerodynamic experimentation and the most significant parameters in the theoretical application; management of experimental techniques, equipment and measuring instruments; simulation, design, analysis and interpretation of experimentation and operations in flight; systems of maintenance and certification of aircrafts.
C26	Applied knowledge of aerodynamics; mechanics and thermodynamics, flight mechanics, aircraft engineering (fixed and rotary wings), theory of structures.

C28	Appropriate knowledge applied to engineering: foundations of fluid mechanics that describe the flow in any regime and determine the distribution of pressures and aerodynamic forces.
D3	Capability of oral and written communication in native lenguage
D4	Capability of autonomous learning and information management
D5	Capability to solve problems and draw decisions
D6	Capabiliity for interpersonal communication
D8	Capabiliity for critical and self-critical reasoning
D11	Show motivation for quality with sensitivity towards subjects within the scope of the studies

Expected results from this subject

Expected results from this subject	Training and Learning Results		
Conocimiento y comprensión de los principales conceptos y técnicas de la Mecánica de Fluidos	A3	C16 C18 C19 C22 C28	D4 D5 D8 D11
Capacidad para aplicar los principales conceptos y técnicas de la Mecánica de Fluidos a las Ciencias de la Ingeniería	A2 A3 A5	C16 C18 C19 C20 C22 C25 C26 C28	D3 D4 D5 D6 D8 D11
Comprensión de los procedimientos básicos de la dinámica de fluidos computacional	A5	C16 C18 C19 C22 C25 C26 C28	D4 D5 D8 D11

Contents

Topic	
CFD. General equations and transport phenomena	Topic 1: Summary of the general equations. Integral notation Differential notation Conservative form. Compact notation Most common limit models Most common boundary conditions
CFD. Turbulence	Topic 2: Introduction to turbulence Introduction Kolmogorov scale Infeasibility of direct numerical simulation Turbulence models: RANS models: -Reynolds and Favre averages -Averaged equations. Apparent Reynolds stresses. closure problem - Boussinesq hypothesis: algebraic models, of one equation and of two equations - Wall laws. High and low Reynolds number models - Reynolds apparent stress transport models LES Models: Description

CFD. Introduction to Computational Fluid Dynamic	Topic 3: FVM methods of numerical resolution of the Navier-Stokes equations. Finite Volume Methods (FVM): - Introduction - Discretization of the computational domain - Discretization of fluid equations - Discretized equations in FVM - Discretization of boundary conditions incompressible flows. pressure equation - Artificial compressibility methods - Pressure-velocity couplings - Most common numerical resolution acceleration methods Topic 4: Introduction to the use of different software (OpenFoam and Fluent*) for numerical simulation of fluids. Practices in computer room. *The use of these software will be conditioned to the availability of use licenses by of the center as well as the correct installation of the same in the assigned computer room Applications: - Laminar flow inside a cavity - Flow in a stream mixing device - Aerodynamic forces on bodies: Flow around an obstacle. laminar flow and turbulent flow Calculation of Kármán street after a blunt body Incompressible flow over airfoil Transonic flow over airfoil -Numerical simulation exercises/projects to be resolved more independently by students.
Fluid Mechanics II. Ideal flows. Irrotational flows.	Topic 1: Irrotational movements. Irrotationality conditions Irrotational Equations of Motion Initial and boundary conditions irrotational movement of liquids superposition principle Speed potential at great distances from an obstacle Irrotational plane motion of liquids: Elementary solutions. Current in nooks and corners. Current around a cylinder with circulation Two-dimensional irrotational motion of gases Prandtl□Meyer expansion Topic 2: Movements with surfaces of discontinuity Equations for the jump of fluid magnitudes in a discontinuity Normal and tangential discontinuities normal shock waves oblique shock waves Application: Almost one-dimensional movement of ideal fluids: Critical area. Movement in nozzles. Loading and unloading in warehouses. Shock waves. Relation of Hugoniot.
Fluid Mechanics II. One dimensional unsteady flow of ideal fluids	Topic 3: Non-stationary one-dimensional motion of ideal fluids. Effect of compressibility in liquids Opening and closing of valves. water hammer Equations of unsteady unidirectional motion in gases. simple waves
Fluid Mechanics II. Low Reynolds flows	Topic 4: Movement at low Reynolds numbers Equations. Initial and boundary conditions Application to incompressible fluids. Movements around a cylinder and a sphere Lubrication: Reynolds Equation of Lubrication 3D. Applications. cylindrical bearing, gas lubrication, rectangular skid, ...

Fluid Mechanics II. Boundary layer	Topic 5: Laminar boundary layer Incompressible laminar boundary layer. similarity solutions. Boundary layer on flat plate. Blausian solution Compressible laminar boundary layer Thermal boundary layer at low speeds
Fluid Mechanics II. Laboratory practicals	-Aerodynamic bench test: boundary layer measurement - Low speed wind tunnel test Pressure distribution on blunt body - Pressure distribution in convergent and convergent-divergent nozzles. Shock waves. sonic blocking

Planning

	Class hours	Hours outside the classroom	Total hours
Laboratory practical	4	5	9
Lecturing	33	35	68
Project based learning	8	18.5	26.5
Practices through ICT	8	0	8
Problem solving	22	73	95
Project	0	15	15
Essay questions exam	1.5	0	1.5
Essay questions exam	1	0	1
Essay questions exam	1	0	1

*The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.

Methodologies

	Description
Laboratory practical	Realización de las prácticas de laboratorio
Lecturing	Exposición de la teoría Traslación de problemas de fluidos a modelos matemáticos para ser resueltos numéricamente
Project based learning	Planteamiento y resolución numérica de problemas propuestos aplicados a flujos de fluidos
Practices through ICT	Planteamiento y resolución de modelos aplicados a flujos de fluidos
Problem solving	Resolución de problemas y/o ejercicios de forma autónoma por parte del alumno para comprender y caracterizar los distintos tipos de movimientos de fluidos y sus simplificaciones

Personalized assistance

Methodologies	**Description**
Laboratory practical	All doubts that arise throughout the development of the practices will be attended personally
Problem solving	As far as possible, all doubts that arise during the resolution of the problems will be addressed.
Practices through ICT	In the practices, as much as possible, we will try to organize the group of students in different practices. All doubts that arise throughout the development of the practices will be attended personally
Tests	**Description**
Project	Doubts that arise throughout the development of the project will be addressed in tutorials

Assessment

	Description	Qualification	Training and Learning Results		
Project based learning	Preparation and delivery of the proposed CFD simulation report to the student	20	A2 A3 A5	C16 C18 C19 C20 C22 C25 C26 C28	D3 D4 D5 D6 D8 D11

Practices through ICT	Assistance and active participation in CFD practices	1.5	A2 A3 A5	C16 C18 C19 C20 C22 C25 C26 C28	D3 D4 D5 D6 D8 D11
Problem solving	Attendance to the problem solving sessions and delivery of the proposed problems. MFII	3.5	A2 A3 A5	C16 C18 C19 C20 C22 C25 C26 C28	D3 D4 D5 D6 D8 D11
Essay questions exam	Realization of written tests, resolution of exercises, practical cases. MFII	30	A2 A3 A5	C16 C18 C19 C20 C22 C25 C26 C28	D3 D4 D5 D8
Essay questions exam	Realization of written tests, resolution of cases and CFD concepts.	10	A2 A3 A5	C19 C20 C26 C28	D3 D5 D8 D11
Essay questions exam	Realization of written tests, resolution of exercises, practical cases. MFII	35	A3 A5	C18 C19 C22 C25 C26	D4 D5 D8

Other comments on the Evaluation

First call: The evaluation system will be continuous assessment for all students, nevertheless the student has the right to opt for the exam-only assessment according to the procedure and the deadline established by the centre for each call, in which case they will have the possibility of taking a final exam, 5 hours long, (with a break) with a weight of 100% of the grade.

If a student participates in any of the qualifying tests within the continuous assessment, it will be considered as presented to the subject. The continuous assessment is considered until July, so the qualifications achieved in all the activities carried out previously, are maintained until the July call, it will not be saved from one year to another.

The continuous assessment of the subject will be carried out through the following tests and weights:

- 35% Written continuous assessment test on knowledge of MFII.
- 30% Written continuous assessment test on knowledge of MFII.
- 20%. Delivery of the CFD Project/s of numerical simulation proposed to the students by the teaching staff.
- 10% Continuous assessment written test on CFD knowledge
- 3.5% Attendance, delivery of problems proposed by the faculty, and active participation in practical classes and MFII problem solving.
- 1.5% Attendance, delivery of problems proposed by the teaching staff, and active participation in the CFD practice classes.

To pass the subject it will be necessary to obtain a minimum (2 out of 10), in each and every one of the tests carried out, and achieve a 5 out of 10 in the total evaluations.

Second call: All the qualifications obtained previously in each of the continuous assessment tests of the first edition can be maintained from the fist to the second call, the students are going to decide which activities are evaluated again in the second call, with the exception of evacuations concerning to attendance.

End-of -program call, exam-only assessment option with a weight of 100% of the grade.

The student is expected to exhibit appropriate ethical behaviour. In case of detecting unethical behaviour (copying, plagiarism, use of unauthorized electronic devices, for example), it will be considered that the student does not meet the necessary requirements to pass the subject. Depending on the type of unethical behavior detected, it could be concluded that the student did not achieve the necessary skills.

The use of any electronic device during the evaluation tests will not be allowed unless expressly authorized. The fact of introducing an unauthorized electronic device into the exam room will be considered a reason for not passing the subject in this academic year and the overall grade will be failed (0.0).

Sources of information

Basic Bibliography

White, F.M, **Viscous fluid flow**, 3rd ed., McGraw-Hill, 2006

Panton, R. L., **Incompressible Flow**, 4th Edition, Wiley, 2013

Anderson, **Modern Compressible Flow**, 3nd Ed., Mc Graw Hill, 1992

BARRERO & PÉREZ-SABORID, **Fundamentos y aplicaciones de la Mecánica de Fluidos**, Mc Graw Hill, 2005

BLAZEK, J., **Computacional Fluid Dynamics: Principles and Applications**, Elsevier, 2001

H K Versteeg and W Malalasekera, **An Introduction to Computational Fluid Dynamics THE FINITE VOLUME METHOD**, 2nd Ed., Prentice Hall, 2007

Complementary Bibliography

Kundu , C., **Fluid Mechanics**, 4th Edition,, Academic Press, 2010

SCHLICHTING, H, **Boundary Layer Theory**, Mc Graw Hill, 1987

FERZIGER, J., MILOVAN, P., **Computational Methods for fluid Dynamics,**, Springer, 1999

F. Moukalled L. Mangani M. Darwish, **The Finite Volume Method in Computational Fluid Dynamics An Advanced Introduction with OpenFOAM® and Matlab®**, Springer, 2016

WILCOX, **Turbulence Modeling**, DCW Industries, 2004

www.openfoam.com,

Recommendations

Subjects that it is recommended to have taken before

Mathematics: Mathematical methods/O07G410V01301
Fluid mechanics/O07G410V01402

Other comments

Dedicate the indicated time to assigned personal work, as well as resort to personal tutorials with the teacher to resolve any possible doubts that may arise during the student's personal work

A full follow-up of the subject is recommended, as well as an active attitude in the classes.