Universidade Vigo

IDENTIFYING DATA				
Advanced fluid mechanics				
Subject	Advanced fluid mechanics			
Code	O07M197V01104			
Study programme	(*)Máster Universitario en Enxeñería Aeronáutica			
Descriptors	ECTS Credits	Choose	Year	Quadmester
	6	Mandatory	1st	1st
Teaching language	Spanish			
Department				
Coordinator	Martín Ortega, Elena Beatriz			
Lecturers	Martín Ortega, Elena Beatriz			
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Web				
General description	Subject that includes advanced knowledge of fluid flows, from a theoretical and numerical perpective, including also reactive flows.			

Training and Learning Results	
Code	
A2	Adequate knowledge of advanced fluid mechanics, with special emphasis on computational fluid mechanics and turbulence phenomena
A12	Adequate knowledge of advanced fluid mechanics, with special emphasis on experimental and numerical techniques used in fluid mechanics.
A13	Understanding and mastering the phenomena associated with combustion and heat and mass transfer.

Expected results from this subject	
Expected results from this subject	Training and Learning Results
Know how to analyse flows (both incompresible and compressible flows, including flows with combustion) by means Computational Dynamics Techniques In this subject, we will focus on: - using numerical and/or analytical methods to solve a fluid flow problem - Working by projects	A2 A12 A13

Contents	
Topic	
1. REVISION OF NAVIER-STOKES EQUATIONS	1.1. Principles of conservation of mass, linear momentum and energy. 1.2. Euler Equations. 1.3. Initial and boundary condiitions 1.4. Dimensionless formulation, dimensionless parameters and physical similarity. Application to Rayleigh problem.
2. BOUNDARY LAYERS	2.1 Introduction. Equations of the boundary layer. Introduction to perturbations. Thicknesses and general considerations. Laminar boundary layers 2.2. Integral equation of Karman. 2.3. Blausius Solution. Effects of suction/blown. 2.4. Solutions of Falkner-Skan. 2.5. Thermal bpundary layer 2.6. Effects of compressibility. Boundary layers at very high speed

2. NAVIER-STOKES EQUATIONS FOR REACTIVE MIXTURES	2.1 Multicomponents mixtures: molar Fraction. Mass fraction. Equation of state. Speed of diffusion. 2.2 Conservation Equation for the chemical species. Molecular transport in multicomponents mixtures. Navier-Stokes Equations for reactive flows 2.3 Introduction to the chemistry of combustion. Global and elementary reactions. Dependency of the constants of reaction with the temperature. Hypothesis of steady state. Hypothesis partial equilibrium 2.4 Thermokinetics. Steichometry and dosage. Adibatic flame temperature. Chemical balance. 2.5 Length and time scales. Relevant dimensionless numbers 2.6 Applications. Numerical simulation of combustion processes
3. TURBULENCE	3.1 I Review of properties of turbulence. Free turbulence. Turbulent dynamic boundary layer. Turbulent thermal boundary layer 3.2 RANS and LES models.
4.ADVANCED NUMERICAL TECHNIQUES IN FLUID DYNAMICS	4.1 Finite Volume Methods (FVM) 4.2 Implementation of the FVM 4.3 Pressure based methods. Density based methods 4.4 Examples of discretisation 4.5 Residuals and their meaning. 4.6 Numerical Simulation of different compressible and incompresible flows
5. INTRODUCTION TO EXPERIMENTAL MEASUREMENTS IN FLUIDS	5.1. Characterisation of Turbulent Flow 5.2. Measurement of Temperature and Heat flow 5.3 Measure of Pressure 5.4 Measure of forces 5.5 Hot-wire anemometer. 5.6 Laser anemometer 5.7 Other measurement and visualisation techniques for fluids

Planning

	Class hours	Hours outside the classroom	Total hours
Lecturing	29	0	29
Practices through ICT	16.5	0	16.5
Mentored work	0	62	62
Problem solving	0	40	40
Problem and/or exercise solving	2.5	0	2.5

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

Methodologies

	Description
Lecturing	Explanation by the professor of the contents on the subject of study, the theoretical bases and/or the guidelines for work, exercise or project to be developed by the student.
Practices through ICT	Activities of application of knowledge to specific situations, and of acquisition of basic skills related with the subject of study in the informatic partical classes of simulation of flows
Mentored work	Activity in which one or several longer problems are formulated, where the student has to apply the knowledge acquired in the masterclasses and in the numerical simulation classes.
Problem solving	Activity in which problems and/or short exercises related with the subject are formulated. The student has to find the correct solutions by means of the application of procedures, use of available information. The student has to interpretate the obtained results. It is a complementary activity to the lectures

Personalized assistance

Methodologies	Description
Lecturing	Student questions formulated during the lectures will be addressed, as well as questions asked during the computer practices. Likewise, students will be attended personaly during the subject tutorships.

Practices through ICT	Student questions formulated during the lectures will be addressed, as well as questions asked during the computer practices. Likewise, students will be attended personaly during the subject tutorships.
Mentored work	Students will be attended personaly during the subject tutorships.
Problem solving	Students will be attended personaly during the subject tutorships.

Assessment

	Description	Qualification	Training and Learning Results
Mentored work	Evaluation task in which the student solves numerically a specific flow problem asigned by the professor. The student will analyse it and will resolve the problem using the numerical techniques. The work will be uploaded to the Moovi platform befor the oficial date of the exam	40	A2 A12 A13
Problem solving	Relization of two examinations. These exams can include enclosed questions with different alternative of answer (true/false, multiple election, pairing of elements...), or the application of the knowledge to the resolution of specific problems of fluids, or the realisation of a work of numerical simulation nature. Each one of the examinatiions will have a weight of 30% on the final note of the subject. One of these two exams will take place in the oficial final exam date	60	A2 A12 A13

Other comments on the Evaluation

First opportunity evaluation:

To pass the subject in the 1st opportunity, the mark should be equal or greater than 5 points over 10 when averaging the marks of all the exams, works and the final mark of the exam carried out during the official exam date.

The student has right to opt for a global examination in a unique exam. To opt for this, the student should follow the official procedure established by the school.

Global Evaluation:

It will consist on a unique examduring the official date, that includes all the contents of the subject, including the contents and methods used in the cases of study. The marks obtained in this exam should be equal or greater than 5 points over 10 in order to pass the subject

The exams calendar will be publish in the oficial web page of the school

Second opportunity evaluation:

The students will take an exam taht include contents of all the subject, if the final note of the exams and works done durig the teaching period is lower that 5 points over 10.

End of studies exam:

For the evaluation of end of studies exam, an exam during the oficial date set by the school will be taken by the students enrolled in this type of exams. The exam will include all contents. To pass the subject, the student must obtain a mark equal or greater than 5 over 10.

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

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

Complementary Bibliography

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

Stavros Tavoularis, **Measurement in Fluid Mechanics**, Cambridge University Press,, 2005

GLASSMAN, **Combustion**, 4th edition, Elsevier, 2008

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www,openfoam.com,

Recommendations

Other comments

Devote the time indicated for personal work, as well as use the personal tutorships with the professor to solve the possible doubts that arise during the personal work of the student.

It is recommended to study continuosly from the very beginning of the subject as well as to mantain an active attitude in the classes.