UNIVERSIDADE DA CORUÑA

Teaching Guide				
Identifying Data			2022/23	
Subject (*)	Introduction to Marine Computational Fluid Dynamics (CFD)	Code	730542011	
Study programme	Master Universitario Erasmus Mundus en Sostibilidade e Industria 4.0 aplicada ao Sector Marítimo			
Descriptors				
Cycle	Period	Year	Type	Credits
Official Master's Degree	2nd four-month period	First	Obligatory	6
Language	English			
Teaching method	Face-to-face			
Prerequisites				
Department	Enxeñaría Naval e Industrial			
Coordinador	Gosset , Anne Marie Elisabeth	E-mail	anne.gosset@udc.es	
Lecturers	Gosset , Anne Marie Elisabeth Lema Rodríguez, Marcos	E-mail	anne.gosset@udc.es marcos.lema@udc.es	
Web	http://www.master-seas40.unina.it			
General description	This course is focused on providing the students with an introduction to the field of computational fluid dynamics, with an application to the marine field. The course will cover from the basic principles of conservation and their characteristic equations, its discretization methods, to the finite-volume method and the basics of the CFD codes used for their solution, with a focus in the open source code OpenFoam.			

Study programme competences / results	
Code	Study programme competences / results
A2	CE2 - Demonstrate knowledge, understanding and competences in using model and simulation tools related with ship structures, motions and fluid dynamics (SIM).
B2	CB6 - Acquire and understand knowledge that provides a basis or opportunity to be original in the development and / or application of ideas, usually in a research context.
B3	CB7 - That students know how to apply the acquired knowledge and their ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.
B4	CB8 - That students are able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgments.
B5	CB9 ? That students are able to communicate their conclusions -and the knowledge and ultimate reasons that sustain them- to specialized and non-specialized publics in a clear and unambiguous way.
B6	CB10 - That students have the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.
B7	CG1 ? To display the adequate intercultural competence to successfully navigating within multicultural learning environments and to implement basic management principles suitable for a multicultural working environment.
B8	CG2 ? To express an attitude of intellectual inquisitiveness and open-mindedness.
B11	CG5 ? To have the capability to identify, formulate and solve engineering problems within realistic constraints.
B13	CG7 ? To have the capability to critically analyse, synthesise, interpret and summarise complex scientific processes.
C2	CT2 - Mastering oral and written expression in a foreign language.
C4	CT4 - Acting as a respectful citizen according to democratic cultures and human rights and with a gender perspective.
C6	CT6 - Acquiring skills for healthy lifestyles, and healthy habits and routines.
C7	CT7 -Developing the ability to work in interdisciplinary or transdisciplinary teams in order to offer proposals that can contribute to a sustainable environmental, economic, political and social development.

Learning outcomes	
Learning outcomes	Study programme competences / results

Capacity to understand the basic concepts of computational fluid dynamics and to describe physical problems in this field with adequate mathematical models. Capacity to set up test cases related with the fluid dynamics in the marine field and to solve problems related with numerical and physical errors.	AC2	BC1 BC2 BC3 BC4 BC5 BC6 BC7 BC10 BC12	CC2 CC4 CC6 CC7

Contents	
Topic	**Sub-topic**
Chapter 1. Conservation laws in fluid dynamics (reminder)	1. Principles of conservation in continuum 2. Constitutive equation of fluids 3. Fluid dynamics conservation equations in differential form 4. Initial and boundary conditions 5. Boundary layers and turbulent flows
Chapter 2. Finite volumes method I	1. Discretization methods for Partial Differencial Equations 2. Phiiosophy of Finite Volumes method compared to Finite Differences and Finite Elements 2. Finite Volumes for diffusion problems 3. Finite Volumes for convection-diffusion problems. Resolution of a problem with Matlab as ICT exercise.
Chapter 3. Finite volumes method II	1. Pressure-velocity coupling in steady flows: Concept of staggered grid, SIMPLE algorithm 2. Pressure-velocity coupling in unsteady flows: PISO algorithm. Resolution of a problem with Matlab as ICT exercise. 3. Programming of initial and boundary conditions
Chapter 4. Introduction to CFD	1. History of CFD computation 2. Identification of adequate models and approximations in CFD 3. Workflow of CFD simulations: Pre-processing, processing and post-processing 4. Introduction to OpenFoam. C++ reminder and structure of the code.
Chapter 5. Pre-processing of a CFD simulation	1. Mesh generation. Open-source solutions with OpenFoam. 2. Boundary conditions 3. Initial conditions ICT exercise with a simple test case in OpenFoam.
Chapter 6. Processing	1. Solver parametrization 2. Steady and unsteady solvers: time control and solution 3. Convergence of the computation: Monitoring the residuals and the solution ICT exercise with a simple test case.
Chapter 7. Post-processing	1. Post-processing with paraView 2. Utilities in Openfoam 3. Verification and validation of results 4. Evaluation of uncertainty in CFD simulations ICT exercise with a simple test case. Introduction to programming in OpenFoam.

Chapter 8. Turbulence and boundary layers in CFD	1. Introduction to turbulence 2. Boundary layers and their modeling in CFD 3. Different strategies for turbulence modeling 4. Wall treatment in CFD 5. Relevance in marine applications ICT exercise with a characteristic test case in the marine field

Planning				
Methodologies / tests	Competencies / Results	Teaching hours (in-person & virtual)	Student?s personal work hours	Total hours
ICT practicals	A2 B2 B3 B4 B6 B11 B13 C7	15	45	60
Supervised projects	A2 B2 B3 B4 B5 B6 B7 B8 B11 B13 C2	3	30	33
Oral presentation	B4 B5 B7 B8 B13 C2 C4 C6	2	8	10
Mixed objective/subjective test	A2 B3 B6 B8 B11 B13 C2	3	0	3
Guest lecture / keynote speech	A2 B2 B3 B6 B7 B8 B11 B13	21	21	42
Personalized attention		2	0	2
(*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students.				

Methodologies	
Methodologies	Description
ICT practicals	Methodology that allows students to learn effectively, through practical activities (calculations and simulations) the theory of fluid mechanics, through the use of information and Communication Technologies.
Supervised projects	Methodology designed to promote the autonomous learning of students, with the tutoring of the teacher in class. This teaching system is based on two basic elements: the independent learning of the students and the follow-up of this learning by the teacher-tutor. In this sense, several exercises will be carried out throughout the course during and outside class hours to continuously monitor the students' learning process in the subject.
Oral presentation	Presentation of the students to their peers of the results obtained in their individual tutored work. The presentation is followed by a Q&A session with the professor and the other students.
Mixed objective/subjective test	Final evaluation exam consisting in a written test in which it will be necessary to answer different types of theoretical questions as well as to solve problems.
Guest lecture / keynote speech	Face-to-face activity in the classroom that serves to establish the fundamental concepts of the subject. It consists of oral presentation complemented with the use of audiovisual media and the introduction of some questions addressed to students, in order to transmit knowledge and facilitate learning.

Personalized attention	
Methodologies	Description

ICT practicals Supervised projects	ICT exercices will consist in basic programming in Matlab, as well as a familiarization with the open source CFD OpenFoam code, including basic tutorials with mesh generation, solver parameterization, and post-processing of results. This activity will be carried out under the direction of the professor, who will solve all the difficulties that students face. Tutored work will consist in programming basic finite volume methods in Matlab, and solving a case study with OpenFoam. It will start in the classroom with the support of the professor to solve a maximum of doubts and the student will finish it autonomously.

Assessment			
Methodologies	Competencies / Results	Description	**Qualification**
Supervised projects	A2 B2 B3 B4 B5 B6 B7 B8 B11 B13 C2	Evaluation of a report based on the results obtained in the tutored works.	60
Oral presentation	B4 B5 B7 B8 B13 C2 C4 C6	Oral presentation of the tutored work results and Q&A session with the professors and other students.	10
Mixed objective/subjective test	A2 B3 B6 B8 B11 B13 C2	Written exam focused on the theoretical concepts developed in the class.	30

Assessment comments
The written exam will consist in a quizz followed by a several questions that need a higher level of reasoning and development. Failure to reach a minimum grade of 4/10 in the exam will impede success in this course.Tutored works will be individual or in pairs; there will one individual for the first part of the course (basics of finite volumes) and one for the second part (CFD simulation of a test case) carried out in pairs. It will be necessary to deliver the reports in time and form. In addition, it will require a public oral defense. The report and the presentation given as well as the answers to the professor's questions during the compulsory presentation will be taken into account for the evaluation of this activity. Failure to make the presentation will result in a grade of zero. General evaluation criteria: * Clarity, extent and quality of report. * Clarity and quality of oral presentation of the work. * Mastery of the topic and adequacy of the student's answers to the teacher's questions in the presentation session. In this subject no academic dispensation is accepted. The evaluation criteria of the second opportunity are the same as in the first.If a student fails to pass the course at the first opportunity, at the second opportunity they will only be able to submit the review and improvement of those works and exercise delivered and previously qualified as unsuitable.There will be a second opportunity for the exam.General EMJMD Sustainable Ship and Shipping SEAS 4.0 evaluation rules: - Students will have only two oportunities to pass a course. If failing to do so, they may be forced to leave the degree. - No part time or lecture attendance exemption are allowed in this degree.

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Sources of information	
Basic	- H K Versteeg, W. Malalasekera (2007). An introduction to Computational Fluid Dynamics. Pearson. Prentice Hall - J. D. Anderson (1995). Computational fluid dynamics. The basics with applications.. McGraw-Hill Education - C. J. Greenshields (2018). OpenFoam User guide. Version 6. The OpenFoam Foundation - J H Ferziger, M. Peric (2001). Computational Methods for Fluid Dynamics. Springer - C.J. Greenshields, H. Weller (2022). Notes on Computational Fluid Dynamics: General Principles. CFD Direct
Complementary	

Recommendations
Subjects that it is recommended to have taken before
Subjects that are recommended to be taken simultaneously
Subjects that continue the syllabus
Innovative CFD Approaches/730542030
Other comments
To help in achieving a sustainable environment and to get the objective of number 5 action of the "Ferrol Green Campus Action Plan" (Healthy and environmentaly and socially sustainable research and teaching):The assignments to be done in this course:- Will be required in digital format.- Will be delivered using Moodle, with no need to print them.In case it is necessary to print them:- Plastics won´t be used.- Two side printing will be used.- Recycled paper will be used.- Printing drafts will be avoided.A sustainable use of the resources should be done, together with the prevention of negative impacts on the environment.