REM master basic syllabus

Title:
CFDFTF Computational fluid dynamics for turbulent flows

Credit value:
3 ECTS

Mandatory/Optional:
Optional

Semester:
2

Lecturer/s:
Johan Jansson, Ali Ramezani, Goran Stipcich

University:
BCAM – Basque Center for Applied Mathematics & UPV – University of the Basque Country

Department:
Mathematics

Rationale:
In the framework of renewable energies, the study of the effects of fluid dynamics is crucial for the efficiency and performance when designing a device for energy extraction. The course covers the fundamentals of the theory and numerical simulation of fluid flow, encompassing turbulence effects in applications such as flow around platforms and turbines, etc. The mesh generation process, including goal-oriented adaptive mesh refinement, will also be tackled, since it is an essential and time-consuming component in the design process.

Objectives:
The students will learn the fundamentals concepts and mathematical background of computational fluid dynamics (CFD). They will learn to set-up numerical simulations for aerodynamics applications from scratch through practical hands-on sessions. They will be able to select the suitable numerical set-up for the different flow conditions. The basic knowledge will be provided for post-processing and evaluating the results in terms of numerical reliability, aerodynamic forces and performance of a designed geometry.

Skills: *(according to the list of skills provided)*

Subject skills	**REM Master Skills**						
	L2.1	**L2.2**	**L2.3**	**L2.4**	**L2.5**	**L2.6**	**L2.7**
L3.1. Ability to learn the fundamental fluid dynamics equations, their derivation and physical interpretation.	X			X			
L3.2. Ability to tackle the solution of a practical problem in aerodynamics, by the use of suitable numerical approximation.	X	X		X			X
L3.3. Ability to handle and understand the basics of the development of a computer program for solving the equations of fluid dynamics.		X					X
L3.4. Ability to produce concise and clear report on the home assignments and to orally discuss it						X	X

Teaching and learning methods:
The main part of the course will be taught by lectures. Nevertheless, a significant portion of the time will be dedicated to hands-on sessions in computer rooms.

Allocation of student time:

	Attendance (classroom, lab,…)	**Non attendance (lecture preparation, self study…)**
Lectures	20 hours	35 hours
Lab	10 hours	/
Assignments	/	15 hours

Assessment:

- *Home assignments: computer program and written report, made individually, and discussed individually (40 % of final mark);*
- *Final written exam (60 % of final mark).*

Assessment Matrix:

Subject skills	**Assessment method**			
	Exam	**Home work**	**Report**	**Presentation**
L3.1.	60 %	20 %	20 %	
L3.2.	20 %	40 %	40 %	
L3.3.		40 %	30 %	30 %
L3.4.			40 %	60 %

Programme:

Lesson 1	***Introduction to fluid dynamics (A. Ramezani & G. Stipcich)*** *Introduction to Computational Fluid Dynamics (CFD), proprieties of a fluid, conservation principles, derivation of equations of fluid dynamics, discretization techniques: finite differences, finite volume, finite element* *Distribution (6 h theory + 10h assignments)*
Lesson 2	***Meshing techniques (A. Ramezani & G. Stipcich)*** *Structured meshes, unstructured meshes, mesh adaptivity* *Distribution (2 h theory + 2 h practical classroom + 2h assignments)*
Lesson 3	***General Galerkin (G2) finite element method (J. Jansson)*** *Concept of weak solution, energy estimates for the underlying equations and G2 approximations, a posteriori output error estimates for G2 using duality, analysis of the global effect of friction boundary conditions in G2 computations* *Distribution (16 h theory)*
Lesson 4	***Training in FeniCS framework (J. Jansson)*** *Use G2 software for adaptive turbulent flow computations with error control* *Distribution (4 h practical classroom)*

Resources:

Classrooms, blackboard, laptop, projector and computer room.

Bibliography:

1. *Textbook:* Blazek, J., *Computational Fluid Dynamics: Principles and Applications*, 3rd Edition, Butterworth-Heinemann, 2015.
2. Acheson, D. J., *Elementary Fluid Dynamics*, Oxford Applied Mathematics and Computing Science Series, Oxford University Press, 1990.
3. J. Hoffman and C. Johnson "Computational Turbulent Incompressible Flow", Springer, 2007.

Further comments: