REM master basic syllabus

Title: *NUMHY Numerical hydrodynamics*
Credit value: *5 ECTS*
Mandatory/Optional: *Optional*
Semester: *S3*
Lecturer/s: *David Le Touzé, Lionel Gentaz, Zhe Li*
University: *Ecole Centrale Nantes*
Department: *Fluid mechanics and thermodynamics*
Rationale: *The numerical simulation takes a more and more important role in engineering, both for design and operation. Free-surface hydrodynamic flows present physical specificities leading to different classes of approximation and, in turn, different numerical methods. Understand these numerical methods, their relative positioning, their respective domains of use, and how they are used and developed nowadays in terms of software and hardware is crucial to future engineers in the very innovative domain of MRE.*
Objectives: *The goal of this class is to provide students with an overview of the Computational Fluid Dynamics (CFD) methods and simulation environment for the computation free-surface unsteady flows of ocean engineering. The different methods rely on different physical approximations of the wave-structure interaction problem. The latter approximations are based upon the space-time scales (from hours and km² to seconds and m²) at stake and the engineering objective at aim (energy convertion quantification, design for standard operation, extreme condition design, maintenance operations, etc.). According to the approximations made, different numerical methods can be developed.* *The primary objective is that students gain a clear vision of the use of the different approximations and methods, and of their respective range of application, computational cost, human and resource cost of use, versatility, limitations, ease of use, space discretization (mesh), etc. The methods reviewed range from potential flow theory ones (BEM: Boundary Element Method, HOS: High-Order Spectral), to full description of the Navier-Stokes equations (FD: Finite Differences, FD: Finite Volumes, FE: Finite Elements) associated with interface models (VoF: Volume of Fluid, LS: Level Set).* *For each method, the mathematical model, discretization and implementation principles are explained. Turbulence modeling principles (RANS: Reynolds Averaged Navier-Stokes, LES: Large-Eddy Simulation, hybrid RANS/LES) are provided. The link with the space discretization (structured surfacic meshes, unstructured volumic meshes, meshless...) is detailed. Numerical properties (convergence, stability, consistency) are reviewed.* *Finally, the links between the numerical method and the current simulation environment are developed: existing commercial software, human and computational resources, choice of software depending on the targetted problem, link with hardware (High-Performance Computing, cloud resources)...* *Practical projects using software based on different methods studied in courses (BEM, FV...) are proposed to students with use of commercial software or software developed in Ecole Centrale de Nantes. In other lab works students will have to implement their own simple numerical model.*

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. Explain and demonstrate knowledge and understanding of potential flow models and BEM	X			X			
L3.2. Explain and demonstrate knowledge and understanding of methods to solve Navier-Stokes equations (FD, FV)	X			X			
L3.3. Explain and demonstrate knowledge and understanding of turbulence (RANS, LES) and interface (VoF, LS) models	X			X			
L3.4. Explain knowledge and understanding of the different components of numerical hydrodynamic simulations: mesher, hydrodynamic solver, hardware			X			X	
L3.5. Apply acquired knowledge to elaborate and implement numerical solver of typical hydrodynamic problems		X		X			X
L3.6. Acquire new skills, organize information and conduct effective reports						X	

Teaching and learning methods:

The course is based on lectures for the theoretical part. It is divided into 3 parts as described in the program.

In addition to master classes, classroom tutorials and computer practices are organized. The latter are done in small groups of students.

Allocation of student time:

	Attendance (classroom, lab,…)	**Non attendance (lecture preparation, self study…)**
Lectures	12 hours	28 hours
Tutorials	6 hours	15 hours
Lab (computer)	14 hours	50 hours

Assessment:

The assessment of this course is based on a final written exam that covers the whole range of knowledge taught in the lectures. In addition, the different computer lab works will lead to the writing of reports that will be evaluated.

Assessment Matrix:

Subject skills	Assessment method	
	Exam	**Report**
L3.1.	65%	35%
L3.2.	65%	35%
L3.3.	65%	35%
L3.4.	100%	0%
L3.5.	0%	100%
L3.6.	0%	100%

Programme:

Lesson 1	***Knowledge and understanding of potential flow solvers*** *Potential flow methods (BEM), Integral methods solving, Surface meshing, Hydrodynamic loading calculation* *4h theory + 2h tutorials + 2h computer lab work*
Lesson 2	***Numerical methods for free surface flows*** *Volumic discretization methods (FD, FV), Time integration and stability, Turbulence models (RANS, LES)* *4h theory + 4h tutorials*
Lesson 3	***Navier-Stokes equations solution techniques*** *Pressure-velocity coupling, Linear system solving, Volumic meshing* *Hydrodynamic loading calculation, Interface methods (VoF, LS)* *4h theory + 24h computer lab work*

Resources:
Classrooms with blackboard and projector
Computer rooms with blackboard and projector

Bibliography:

- H. Lomax et al., *Fundamentals of Computational Fluid Dynamics*, Springer, 2011
- B. Andersson et al., *Computational Fluid Dynamics for engineers*, Cambridge Univ. Press,2011
- J.H. Ferziger, M. Peric, *Computational Methods for Fluid Dynamics*, Springer, 1997
- J.F. Wendt, *Computational Fluid Dynamics, an introduction*, Springer, 2009
- R.H. Nichols, *Turbulence Models and Their Application to Complex Flows*, Univ. Alabama, 2012
- V. Bertram, *Practical Ship Hydrodynamics*, Elsevier, 2012

Further comments: