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# ENGINEERING PROGRAMME

2021-2022

2nd year / 3rd year

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Specialisation option

**Ocean: Hydrodynamics and  
Marine Engineering**

OD OCEAN

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PROGRAMME SUPERVISOR

Félicien BONNEFOY



# 1st Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73 / 93	12	Core course	ENVMA HNUM1 INTHY TEMER	Marine environment and hydrodynamic loads Numerical hydrodynamics: part 1 Introduction to hydrodynamics Seakeeping and stability
UE 74 / 94	13	Core course	HNUM2 HYDEX MANCR P1OCEAN PRPOR	Numerical hydrodynamics: part 2 Experimental Hydrodynamics Ship manoeuvrability and moorings Project: part 1 Lifting bodies & propulsion

# 2nd Semester

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Course unit	ECTS Credits	Track	Course code	Title
UE 103 / 83	14	Core course	APPRO CONAV EOLIEN INTFS P2OCEAN	Advanced hydrodynamics Shipbuilding and maritime economy Offshore Wind Energy Fluid-structure interaction Project: part 2

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 73 / 93

# Marine environment and hydrodynamic loads [ENVMA]

LEAD PROFESSOR(S): *Félicien BONNEFOY / Guillaume DUCROZET*

### Objectives

This course presents classical models used to model surface waves, with specific attention paid to hypothesis and limits of each of the models for hydrodynamic and ocean engineering. The extension to real sea states is presented with an introduction to hindcast models. The response (movement, loading etc) of marine structures to these wave fields is also studied. Finally, the analysis of extreme waves and/or extreme responses is introduced.

### Course contents

- Introduction
- Gravity waves
  - General equations - multiple scales
  - Dispersive waves
    - o Linear (Airy Wave)
    - o Non-linear models (Stokes, stream function, etc)
    - o Refraction of gravity waves
  - Non-dispersive waves (shallow water)
    - o Boussinesq equations
    - o Solitary wave
    - o KdV equation; cnoidal wave
- Statistical models
  - Irregular wave fields modeling
  - Usual wave spectra
  - Generation and propagation of sea states on a large scale
- Loadings and response
  - Loadings on small bodies
  - Response of large bodies to real sea states

### Course material

Water wave mechanics for engineers and scientists, Robert G. Dean & Robert A. Dalrymple, Advanced Series on Ocean Engineering (vol.2)

Water waves and ship hydrodynamics: an introduction, A.J. Hermans

Theory and application of ocean surface waves, C.C. Mei, M. Stiassnie & D.K.P. Yue, Advanced Series on Ocean Engineering (vol.23). Part I: Linear aspects; Part II: Non-linear aspects

### Assessment

Collective assessment: EVC 1 (coefficient 0.5)

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	4 hrs	10 hrs	0 hrs	2 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 73 / 93

# Numerical hydrodynamics: part 1 [HNUM1]

LEAD PROFESSOR(S): *Félicien BONNEFOY / Lionel GENTAZ*

### Objectives

The first part of the course deals with numerical panel methods (or BEM for Boundary Element Methods) based on potential flow model. Flows generated by singularities and integral equations are first introduced; then Fredholm equations are obtained and discretised. These methods are applied in the case of ship resistance problems. Lab work covers the implementation of a panel method in a basic case and use of ship resistance solvers based on potential flow model.

The second part focuses on the introduction of finite difference schemes to discretise and solve partial derivative problems. In lab work the problem of a laminar boundary flow on a flat plate is solved by students who have to implement a numerical solver based on finite difference schemes.

### Course contents

#### Panel methods

- potential flow model
- elementary singularities: source, sink, dipole, vortex
- continuous distribution of singularities
- integral equations
- Fredholm equation
- discretisation and numerical solution: panel method
- how to take influence of free surface into account?

#### Ship resistance

- Froude hypothesis; decomposition of the total ship drag
- numerical treatment using panel method
- examples of results given by panel methods: advantages and limitations

#### Finite difference schemes

- definition of finite difference schemes
- definition of consistency, stability, convergence
- influence of schemes (centered or non-centered) on stability
- generalisation to discretization of Navier-Stokes equations

### Course material

V. Bertram, Practical Ship Hydrodynamics, 2000

G. Delhommeau, les problèmes de diffraction-radiation et de résistance de vagues: étude théorique et résolution numérique par la méthode des singularités, 1987

### Assessment

Collective assessment: EVC 1 (coefficient 0.6)

Individual assessment: EVI 1 (coefficient 0.4)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	8 hrs	4 hrs	18 hrs	0 hrs	2 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 73 / 93

# Introduction to hydrodynamics [INTHY]

LEAD PROFESSOR(S): David LE TOUZÉ / Félicien BONNEFOY

### Objectives

This introduction aims at:

- giving elements on the main problems of marine engineering hydrodynamics, and related numerical simulation,
- providing refresher on fluid mechanics,
- presenting modeling elements which will be used throughout the specialization.

### Course contents

- Conference on hydrodynamics issues in marine engineering which are relevant today for industry or research
- Classes of flow modeling in hydrodynamics: main kinds of free-surface hydrodynamic problems; Navier-Stokes equations and free-surface boundary conditions; Euler equations, potential flow model; which flow modeling should be used for which marine engineering hydrodynamic problem
- Introduction to boundary layer and turbulence: order of magnitude analysis of Navier-Stokes equations; concept of boundary layer and characteristic scales; laminar and turbulent boundary layer theories; statistical approach of turbulence; wall turbulent flow
- Introduction to numerical simulation: methodology for numerically simulating a physical problem; specificities of the numerical simulation in marine engineering hydrodynamics; connections between problems and methods; elements on meshing, solving, pre- and post-processing, software/hardware links

### Course material

### Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	26 hrs	4 hrs	0 hrs	0 hrs	2 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 73 / 93

# Seakeeping and stability [TEMER]

LEAD PROFESSOR(S): *Félicien BONNEFOY / Pierre FERRANT*

### Objectives

This course is divided into two parts:

The first part deals with the behavior of marine structures in waves as a part of the linearized theory of fluid-structure interactions using deterministic approaches. Frequency and time approaches are discussed. Moreover, the fundamental relationships between these solutions are systematically underlined. The effects of the second order low and high frequency are also covered. An application is provided based on a solver (frequency domain, linearized free surface conditions and body location) commonly used in engineering.

In the second part which addresses ship stability, general ship aspects are presented and intact and damaged stability are investigated. Computer lab work is completed using state of the art industry software.

### Course contents

#### Seakeeping

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- 1 Objectives, theoretical framework
- 2 Short review of linear systems theory
- 3 Formulation of the boundary value problem. Linearization
- 4 Frequency domain approach
  - a) Definition of diffraction and radiation sub-problems
  - b) Hydrodynamic loads: added mass and damping
  - c) Calculation of motions
  - d) Relations between elementary solutions
- 5 Time domain approach
  - a) Forced motion of a floating body
  - b) Formulation of the diffraction problem in the time domain
  - c) Equations of motion
  - d) Relation to frequency domain response
- 6 Second order effects
  - a) Drift forces
  - b) Low and high frequency loading in irregular waves
- 7 Introduction to nonlinear models
  - a) Nonlinear hydrostatics and Froude-Krylov loading
  - b) Weak scattered hypothesis
  - c) Fully nonlinear models

#### Ship stability

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- properties and equilibrium of a floating body
- motions of the floating body

- specific problems of stability
- transversal angles
- regulation calculations of stability

Lab work is proposed using state of the art industry software to solve ship stability.

## Course material

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J.N. Newman (1977) Marine Hydrodynamics, MIT Press.

O.M. Faltinsen (1990) Sea Loads on Ships and Offshore Structures, Cambridge University Press.

1991, Statique des corps flottants, cours ENSM

R. Servières, 1992, Théorie du navire, ENSTA

R. Hervieu, 1985, Statique du navire, Éditions Masson, Paris,

Résolution A.749: code on intact stability for all types of ship covered by IMO instruments

Chapters II-1 of SOLAS: convention internationale de 1974 sur la sauvegarde de la vie humaine en mer, à jour des amendements en vigueur)

## Assessment

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Collective assessment: EVC 1 (coefficient 0.6)

Individual assessment: EVI 1 (coefficient 0.4)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	20 hrs	4 hrs	8 hrs	0 hrs	2 hrs



## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 74 / 94

# Numerical hydrodynamics: part 2 [HNUM2]

LEAD PROFESSOR(S): *Félicien BONNEFOY / Lionel GENTAZ*

### Objectives

This course covers the study of the numerical simulation of viscous flows modeled by Navier-Stokes equations and especially Reynolds Averaged Navier-Stokes Equations (RANS Equations).

Turbulence modelling, state of the art of hydrodynamic problems solved by Navier-Stokes solvers in industry, velocity-pressure coupling, treatment of the free surface, methods used to solve large and sparse linear systems and introduction to discretisation of partial derivative equations by Finite Volume schemes are investigated.

During lab work the Navier-Stokes solver Star-CCM+ is used by students for academic cases: lid-driven cavity problem, Poiseuille flow, turbulent flow over periodic hills. The Navier-Stokes solver Fine-Marine is used for the simulation of the flow around a ship with forward speed in calm water.

### Course contents

- turbulence modelling (Reynolds Averaged Navier-Stokes Equations, Large Eddy Simulation, Direct Numerical Simulation)
- state of the art of use of Navier-Stokes solvers for problems treated by companies working in naval engineering or ocean engineering
- velocity-pressure coupling (leading to weakly-coupled or fully-coupled algorithms)
- free surface modelling (free surface tracking or free surface capturing procedures)
- iterative methods to solve large and sparse linear systems obtained by discretisation of Navier-Stokes equations using Finite difference or Finite Volume schemes
- introduction to Finite Volume schemes for discretization of Navier-Stokes equations

### Course material

J.H. Ferziger, M. Peric, Computational Methods for Fluid Dynamics, Springer

### Assessment

Collective assessment: EVC 1 (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	12 hrs	0 hrs	18 hrs	0 hrs	2 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 74 / 94

# Experimental Hydrodynamics [HYDEX]

LEAD PROFESSOR(S): *Félicien BONNEFOY*

### Objectives

This course presents state-of-the-art experimental techniques for naval and offshore hydrodynamics. Experiments in the school's wave and towing tanks, are used as examples.

Ship resistance, self-propulsion tests, manoeuvrability, environmental condition generation (wave, current and wind) are typical topics addressed during the course.

### Course contents

The different aspects of the course are illustrated in tutorial exercises (wave specific signal processing) and practical work (week in the experimental facilities of the LHEEA Lab).

Six experimental lab sessions are included:

- ship resistance in the towing tank
- seakeeping in finite depth (small wave tank)
- seakeeping in deep water
- propeller open water tests
- ship stability
- turbulent boundary layer

### Course material

B. Molin, 2002, Hydrodynamique des structures offshore, Editions Technip

S.A. Hughes, 1995, Physical models and laboratory techniques in coastal engineering, Advanced series on ocean engineering, Vol. 7

N. Newman, Marine Hydrodynamics

O.M. Faltinsen, Sea loads on ships and offshore structures

V. Bertram, Practical Hydrodynamics

S. Chakrabarti, Offshore structure modelling

### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	2 hrs	20 hrs	0 hrs	0 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 74 / 94

# Ship manoeuvrability and moorings [MANCR]

LEAD PROFESSOR(S): *Félicien BONNEFOY*

### Objectives

This course is divided into two parts:

The first part deals with the manoeuvrability of ships or other floating structures, and modelling and applications related to this issue.

The second part covers the main characteristics of moorings used in marine and offshore engineering. Practical application involves using industrial calculation software.

### Course contents

With regard to manoeuvrability, the basic formulation is presented in a modular approach. Experimental and numerical techniques for hydrodynamic model design are given.

With regard to moorings, the necessity of moorings in marine engineering is outlined. The main characteristics of moorings are presented with their associated benefits and drawbacks. State-of-the-art industry software is used for an offshore floating structure with moorings subject to swell and currents so that motions of the structure, load on moorings etc can be evaluated and analysed.

### Course material

E.M. Lewandowski, 2004, The dynamics of marine crafts: manoeuvring and seakeeping, Advanced series on ocean engineering, Vol. 22, World Scientific

V. Bertram, 2000, Practical Ship Hydrodynamics, Butterworth Heinemann

T.I. Fossen, 2011, Handbook of marine craft hydrodynamics and motion control, Wiley

### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	10 hrs	6 hrs	16 hrs	0 hrs	0 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 74 / 94

### Project: part 1 [P1OCEAN]

LEAD PROFESSOR(S): *Félicien BONNEFOY*

#### Objectives

This course is the first part of the 80 hour project conducted across the two semesters. The purpose is to use skills acquired during the Ocean specialisation for practical projects proposed and supervised by Centrale Nantes professors and researchers by or engineers from companies. Students work in teams of 2 to 3 during this project.

#### Course contents

Students select their subject in October. Teams of students work on their subject until January during sessions which are planned in the specialisation's timetable. A presentation of their work is planned at the end of January.

#### Course material

All documents proposed in the different courses of the specialisation.

#### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 1st Semester - Course Unit 74 / 94

# Lifting bodies & propulsion [PRPOR]

LEAD PROFESSOR(S): Antoine DUCOIN / Félicien BONNEFOY

### Objectives

The objective of this course is to provide the fundamentals on methods and physics in order to predict hydrodynamic performance and help in the design of lifting bodies. A large range of methods will be presented based on both potential and viscous flows, and some applications will be covered.

The propulsion class will be helpful to define the main characteristics of propellers, to study the performance, sizing and their applications.

### Course contents

Lifting profile:

Lectures

1- Introduction: Geometrical parameters, physical parameters, similarity parameters, classification of flows

2 - Flow and performance analysis

3/4 - Potential methods: thin profile theory and lifting line theory

5 - Cavitation for lifting profiles

Tutorial: application of the thin profile theory

Lab work: application of the lifting line theory using Matlab - study of viscous and thickness effects using Xfoil

### Course material

### Assessment

Collective assessment: EVC 1 (coefficient 0.6)

Individual assessment: EVI 1 (coefficient 0.4)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	14 hrs	8 hrs	8 hrs	0 hrs	2 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 2nd Semester - Course Unit 103 / 83

# Advanced hydrodynamics [APPRO]

LEAD PROFESSOR(S): David LE TOUZÉ / Félicien BONNEFOY

### Objectives

This course goes into depth on different aspects, relying on elements studied in previous courses:

Part 1 - Multi-objective optimization applied to marine hydrodynamics

Part 2 - Future trends of current numerical methods and emerging methods

Part 3 - Introduction to sailboat dynamics

### Course contents

Part 1 Optimization:

- Presentation of the main optimization algorithms (gradient, genetic, etc.)
- Lab work with use of optimization software: tests of efficiency of the optimization algorithms for a known function; practical case consisting in the optimization of a ship bulbous bow in order to reduce ship resistance.

Part 2 - Future of numerical methods:

- State-of-the-art and future trends of numerical methods applied to free-surface hydrodynamics
- Emerging methods: Finite Volumes (high order and adaptive mesh refinement), Finite Elements, Lattice-Boltzmann Method, Smoothed Particle Hydrodynamics (SPH)
- Case of the SPH method, appropriate for fast dynamics problems (impacts, slamming, wave breaking)
- Lab work with use of SPH software

Part 3 - Introduction to sailboat dynamics:

- Review of loads acting on a sailing boat and study of its equilibrium
- Basics of naval architecture
- Specificities of the ship project for sailing boats
- Visit of a repair shipyard

### Course material

### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	0 hrs	16 hrs	0 hrs	0 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 2nd Semester - Course Unit 103 / 83

# Shipbuilding and maritime economy [CONAV]

LEAD PROFESSOR(S): *Félicien BONNEFOY / Lionel GENTAZ*

### Objectives

The fundamentals on managing ship projects, ship propulsion (definitions, main categories of propulsors) and ship structures are presented. In lab work students have to complete a short design loop. A conference on world maritime economy as well as shipyards visits are also proposed in this course.

### Course contents

1. Shipbuilding
  - management of ship projects :
    - categories of ships
    - ship design loop
    - elements of building of ships
  - energy on board :
    - production of energy and examples
  - ship propulsion :
    - decomposition of ship resistance
    - usual propulsion by propeller
    - other propulsors used in shipbuilding
  - ship structure :
    - definitions
    - resistance of materials
    - calculation of needed structures based on local and global stresses
2. Maritime transportation
  - maritime transportation role in the world economy
  - organization of maritime transportation
  - present and future issues

### Course material

### Assessment

Collective assessment: EVC 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	2 hrs	10 hrs	0 hrs	2 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 2nd Semester - Course Unit 103 / 83

# Offshore Wind Energy [EOLIEN]

LEAD PROFESSOR(S): *Félicien BONNEFOY / Sandrine AUBRUN*

### Objectives

- Know the current deployment of onshore and offshore wind energy and the challenges for the future deployments.
- Acquire a good understanding of the wind turbines operation
- Assess performances of single wind turbines or wind farms
- Know the theories and methods related to the floating wind turbine modelling
- Experiment the specific design of floating wind turbines

### Course contents

- Wind resource, potential of installation and wind installed capacity in Europe and in the world. Environmental impacts, economical aspects and costs of wind farm projects
- Wind turbine components and general principles of wind turbine operation (rotor, drive-train, generator...)
- Electricity production and farm effects
- Specificities of offshore wind. Types of bottom-fixed and floating foundations
- Design of floating wind turbines

Some numerical tutorials will be performed to learn how to design a horizontal-axis wind turbine, to assess the wind turbine production and the farm effects, to design floaters and to deal with their coupling with the wind turbines.

### Course material

Introduction to wind energy systems 2013, Springer-Verlag Berlin and Heidelberg GmbH & Co. K

Wind Energy Handbook, 2001 John Wiley & Sons, Ltd

Wind energy explained , - Theory, Design and Application. 2009 John Wiley & Sons, Ltd

Wind resource assessment - A practical guide to developing a wind project. 2012 John Wiley & Sons, Ltd

### Assessment

Collective assessment: EVC 1 (coefficient 0.5)

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	2 hrs	14 hrs	0 hrs	0 hrs



## ENGINEERING - OD OCEAN

2nd year / 3rd year - 2nd Semester - Course Unit 103 / 83

# Fluid-structure interaction [INTFS]

LEAD PROFESSOR(S): Antoine DUCOIN / Félicien BONNEFOY

### Objectives

Part 1- Fundamentals of fluid structure interaction (Antoine Ducoin)

The purpose is to present fundamental aspects for modelling and solving problems of fluid-structure interactions in marine engineering. The different parts cover:

a) Outline of the different types of fluid structure interaction phenomena

-Theory: equilibrium at the fluid structure interface, effect of added mass and stiffness and damping, scaling of a fluid structure interaction problem

-Study of flow induced vibration problems through simple models:

i) flow around a flexible cylinder (forced and free motions), resonance phenomenon

ii) flexible lifting profile: study of static divergence and flutter with potential flow theory

iii) numerical methods in fluid structure interaction: coupling algorithm (space/time, staggered/monolithic etc), algorithms used to deform the mesh, ALE formulation.

Lab work: simulation of a blade deformation using STARCCM+, structural instability analysis

Part 2 - Ship vibrations (Hervé LeSourne)

The objective of these lectures is to provide the fundamentals for an engineer to calculate the vibratory response of a ship.

### Course contents

Part I.

Lecture 1: Introduction and non dimensional analysis

Lecture 2: Flow induced vibration

Lecture 3: Numerical methods

Part 2:

Lecture 1: Ship vibration

### Course material

### Assessment

Collective assessment: EVC 1 (coefficient 0.6)

Individual assessment: EVI 1 (coefficient 0.4)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	18 hrs	4 hrs	8 hrs	0 hrs	2 hrs

## ENGINEERING - OD OCEAN

2nd year / 3rd year - 2nd Semester - Course Unit 103 / 83

### Project: part 2 [P2OCEAN]

LEAD PROFESSOR(S): *Félicien BONNEFOY*

#### Objectives

The purpose of this course is to use the skills acquired during the Ocean specialisation for practical projects proposed and supervised by Centrale Nantes professors and researchers or engineers from companies.  
During the project, students work in teams of 2 or 3 people.

#### Course contents

Teams of students can work on their project and interact with their supervisors during sessions which are planned in the timetable.  
A final project presentation is organized at the end of March.

#### Course material

all documents and books proposed by the lecturers in the different courses of the Ocean specialisation.

#### Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs