Master of Science (MSc)

2025-2026

YEAR 2

MARINE TECHNOLOGY

Hydrodynamics for Ocean Engineering

PROGRAMME SUPERVISORS:
Zhe LI / Guillaume DUCROZET

YEAR 2 - Autumn Semester

CORE COURSES

Course code	Title	ECTS Credits	Page number
TOME3	Tools and Methods for Research 3	5	4
WSINT	Wave-structure Interactions and Moorings	4	5
WWSSM	Water Waves and Sea States Modeling	4	7

ELECTIVES COURSES (three modules from a choice of eight)

Course code	Title	ECTS Credits	Page number
EXPHY	Experimental Hydrodynamics	5	9
MRENE	Marine Renewable Energy	5	10
NAVEN	Naval Engineering	5	12
NUMHY	Numerical Hydrodynamics	5	15
REMHY	Research in Marine Hydrodynamics	5	17
MONIT	Monitoring Strategy and Monitoring Systems	5	19
APPROB	Approximation Methods in Computational Mechanics and Probabilistic Methods in Mechanics	5	21
MUQUANT	Metamodelling and Uncertainty Quantification	5	24

LANGUAGE COURSES (one module from a choice of three)

Course code	Title	ECTS Credits	Page number
CCE3	Cultural and Communication English	2	25
ESP3	Spanish Language	2	26
FLE3	French Language	2	27

* 'French as Foreign Language' except for French native speakers who will study 'Cultural and Communicational English' or Spanish (depending on sufficient demand)

NB Course content may be subject to minor changes

YEAR 2 - Spring Semester

CORE COURSES

Course code	Title	ECTS Credits
THESIS	Internship / Thesis project	30

Page numbers
29

Tools and Methods for Research 3 [TOME3]

LEAD PROFESSOR(S): Guillaume DUCROZET

This project will be devoted to preparatory work for the Master's thesis, which will take place in the second semester.

The main stages are:

- a bibliographical study to identify the key points of the subject and its main difficulties
- setting up the research approach: detailing the various stages and a work plan
- defining the theoretical, numerical or experimental methods required for the research work

This project will be assessed through a written report and an oral presentation.

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

YEAR 2 - Autumn Semester

Wave-structure Interactions and Moorings [WSINT]

LEAD PROFESSOR(S): Vincent LEROY

Objectives

The objective of the first part of the course is to give a complete presentation of the available models for the determination of marine structure response in a seaway, emphasizing the advantages and drawbacks of each approach. A complete presentation of the linearized theory of wave-body interactions, treated in a deterministic sense, is first given. Both frequency domain and time domain approaches are described. Fundamental relations between both solutions are systematically emphasized. High and low-frequency hydrodynamic second-order effects on the response of a floating structure are explained and illustrated. Then, an overview of the available nonlinear theories and numerical models for wave-structure interactions is given. Different levels of approximation are described, from the simple addition of nonlinear hydrostatics to fully nonlinear time domain models.

The second part addresses the modeling of mooring systems. Different options in terms of mooring systems and arrangements are presented in order to give students the main information necessary for undertaking a mooring design process.

For both parts, lectures are completed by practical exercises based on state-of-the-art software for wave-structure interaction and mooring modeling, using both frequency domain and time-domain analysis. The topics of the practical sessions will be realistic ocean engineering problems such as the response of a floating wind turbine platform to waves, for example.

Course contents

Lesson 1 - Objectives, theoretical framework

Lesson 2 - Short review of linear systems theory

Lesson 3 - Formulation of the boundary value problem. Linearization

Lesson 4 - Frequency domain approach

- Definition of diffraction and radiation sub-problems
- Hydrodynamic loads: added mass and damping
- Calculation of motions
- Relations between elementary solutions

Lesson 5 - Time domain approach

- Forced motion of a floating body
- Formulation of the diffraction problem in the time domain

- Equations of motion
- Relation to frequency domain response

Lesson 6 - Second-order effects and introduction to non-linear models

- Drift forces
- Low and high-frequency loading in irregular waves
- Nonlinear hydrostatics and Froude-Krylov loading
- Weak scattered hypothesis
- Fully nonlinear models

Lesson 7 & 8 - Moorings for marine structure

- Some examples in Oil and Gas energy
- Different types of mooring systems
- Offloading operations
- Some examples in Marine Renewable energy
- Mooring main functions
- Mooring arrangement
- Mooring components
- Environmental conditions
- Mooring Design basis

Course material

- J.N. Newman (1977) Marine Hydrodynamics, MIT Press.
- O.M. Faltinsen (1990) Sea Loads on Ships and Offshore Structures, Cambridge University
- Press.
- Adrian Biran (2003) Ship Hydrostatics and Stability, Butterworth-Heinemann.
- API recommended Practice 2SK (2005) Design and analysis of Station-keeping Systems for Floating Structures.
- Vryhof anchors (2010) Anchor Manual, The Guide to Anchoring

Assessment

Collective assessment: EVC 1 (coefficient 0.3)
EVC 2 (coefficient 0.3)
Individual assessment: EVI 1 (coefficient 0.4)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	4	18 hrs	2 hrs	10 hrs	0 hrs	2 hrs

YEAR 2 - Autumn Semester

Water Waves and Sea States Modeling [WWSSM]

LEAD PROFESSOR: Guillaume DUCROZET

Objectives

This course provides an overview of some of the numerous mathematical models used to represent free-surface gravity waves and the associated underlying flow. The models are used to describe the main physical features of ocean wave propagation. The scope is voluntarily restricted to the most useful models generally used by naval engineers and researchers. In a few cases, a deeper theoretical insight is presented in order to allow the students to understand the subtleties of water wave theory and nonlinear physics. In the second part, the use of the statistical approach is presented, both for the representation of sea states and sea structures' responses.

After completing the course, students will be able to:

- Identify the wave theory adequate to model a given regular wave.
- Describe in detail the physics of dispersive waves.
- Develop or use numerical models for the wave propagation.
- Interpret and use Metocean data in the context of ocean engineering.

Course contents

Lesson 1 - Introduction to marine environment

Description of the ocean and the different kind of waves. Focus on gravity waves and the processes responsible for their generation.

Lesson 2 - Gravity wave modelling

Derivation of the governing non-linear equations and introduction of the multiple scale method to generate a particular subset of equations

Lesson 3&4 - Dispersive waves

- Airy Potential; derivation of the solution by separation of variables. Expression of all the related physical quantities: group velocity, energy density, energy flux, limits of the linear model.
- Higher order Stokes solutions (3rd order, 5th order). Sequential construction of the Stokes higher order solutions. Specific nonlinear features of Stokes waves.
- Wave refraction and shoaling in coastal regions.

Lesson 5 – Shallow water (non-dispersive) waves

Derivation of the governing equations and analytical solutions to the problem: solitons and cnoidal waves.

Lesson 6 - Statistical models for wave field description

- Random sea state modeling.
- Usual wave spectra models.
- Wave generation.

Lesson 7 - Random responses of structures at sea

- Random responses of a linear system.
- Review of the results for ship responses by a deterministic theory.
- Motion on a real sea state.
- Extreme responses, and design factors.

Course material

- Robert G. Dean & Robert A. Dalrymple, Water wave mechanics for engineers and scientists, Advanced Series on Ocean Engineering (vol.2).
- A.J. Hermans, Water waves and ship hydrodynamics: an introduction.
- C.C. Mei, M. Stiassnie & D.K.P. Yue, Theory and application of ocean surface waves, Advanced Series on Ocean Engineering (vol.23). Part I: Linear aspects; Part II: Non-linear aspects

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	4	14 hrs	4 hrs	12 hrs	0 hrs	2 hrs

Experimental Hydrodynamics [EXPHY]

LEAD PROFESSOR(S): Félicien BONNEFOY

Objectives

To provide students with state-of-the-art knowledge on experimental fluid dynamics in the field of offshore renewable energy and ship hydrodynamics. Despite the development of numerical modelling, experimental approaches remain a major source of knowledge development in ship hydrodynamics and marine renewable energy. The contribution to the selection of adequate hypotheses and to the validation of analytical or numerical models is of primary importance. In numerous situations, the experimental approach remains the most reliable, economical and fastest way to validate new designs. Specific instrumentation and facilities are presented in this course and used in lab work.

Course contents

Lesson 1 - Introduction to experimental hydrodynamics

- The students discover the main topics in MRE experiments.

Lesson 2 - Experimental ocean engineering

- Experimental tests in offshore basins.

Lesson 3 - Resistance

- Ship resistance and experiments in towing tanks. Reynolds and Froude similitude; extrapolation at full scale.

Lesson 4 - Ship manoeuvrability

- Mathematical formulation, experimental determination of hydrodynamic coefficients. Modelling of towed structures.

Lesson 5 - Measurements and signal processing

- Sensors and transducers, sampling theory. Signal processing, Fourier analysis.

Course material

- S.A. Hughes, Physical Models and Laboratory Techniques in Coastal Engineering
- N. Newman, Marine Hydrodynamics
- O.M. Faltinsen, Sea loads on ships and offshore structures
- V. Bertram, Practical Hydrodynamics
- S. Chakrabarti, Offshore structure modelling

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	12 hrs	0 hrs	20 hrs	0 hrs	0 hrs

YEAR 2 - Autumn Semester

Marine Renewable Energy [MRENE]

LEAD PROFESSOR(S): Sandrine AUBRUN

Objectives

To provide students with (i) a good understanding of the fundamentals of wind turbines, tidal turbines and wave energy converter performance and (ii) a first experience with the assessment of the performance of these technologies.

Course contents

Part 1

Fundamentals of turbine performance. This course is an introduction to the “offshore wind turbines” and “current turbine” classes. The objective is to understand the fundamentals of turbine performance, with a focus on marine applications. We will focus on the main operating principle of turbines, followed by the understanding of flow physics and performance of turbine blades operating in the marine environment.

Part 2

Current turbines. This part of the course will describe, the resource, market and advanced technologies of current turbines. Experimental and numerical methods for studying current turbines will be outlined. An overview of current activities in the field of current turbines will be given. Numerical exercises will aim to calculate the performance of a current turbine in different operating conditions.

Part 3

Offshore wind turbines. Firstly, this part of the course will provide general figures on the installed wind power capacity in the world and in Europe. Then, the components of a wind turbine will be detailed and the general operation principles will be described. Rotor technologies, drive-train and generators, as well as bottom fixed and floating foundations will be addressed. Park effects will be also outlined. Numerical exercises will be carried out in order to investigate the wind turbine aerodynamics, the park effects and to introduce to the challenges linked to the design of floating offshore wind turbines.

Part 4

Wave energy converters The objective of this part of the course is (i) to give to the student a good understanding of the current status of wave energy conversion technologies in terms of potential and actual performance. Thus, it will address first the wave energy resource and market. A historical perspective of wave energy conversion will be given and an overview of the technology will be described. Fundamentals of wave energy conversion and energy performance will be highlighted.

The energy performance of current technologies will be discussed as well as project development methodologies.

Course material

- J. Falnes (2002) Ocean Waves and Oscillating Systems: Linear Interactions Including Wave-Energy Extraction. Cambridge University Press.
- J. Cruz (2008) Ocean Wave Energy: Current Status and Future Perspectives. Springer.
- B. Multon (2011) Marine Renewable Energy Handbook. Wiley.
- J.J. Newman; Marine Hydrodynamics, MIT press, 1977.
- I.H. Abbott, A.E.Von Doenhoff, Theory of wing section, Courier Corporation, 1959.
- J.F. Manwell, J.G. MCGowan & A.L. Rogers (2009) Wind energy explained - Theory, Design and Application. Wiley.
- M. C. Brower (2012) Wind resource assessment - A practical guide to developing a wind project. Wiley.

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	14 hrs	0 hrs	16 hrs	0 hrs	2 hrs

YEAR 2 - Autumn Semester

Naval Engineering [NAVEN]

LEAD PROFESSOR(S): Zhe LI

Objectives

The major objective of this course is to present four important tools in naval engineering applications, which are (1) manoeuverability of ships, (2) multi-objective optimization for minimizing ship resistance, (3) ship resistance calculation with potential flow theory and (4) computational fluid dynamics for ship resistance.

(1) Maneuverability of ships:
In this part, students learn to use the mathematical formulation and analytical resolution of the linearized problem in simple examples such as the case of the turning circles. Realistic configurations are then studied by numerically solving the non-linear problem.

(2) Multi-objective optimization for naval architecture:
In optimization, the multi-objective approach is used in many naval architecture problems. Different algorithms (gradient, genetics, etc.) are presented and the modeFrontier software is used to optimize the bulbous bow of a ship in order to minimize resistance.

(3) Calculation of ship resistance with a potential flow solver:
The purpose is to introduce the ship resistance problem (ship with forward speed in calm water) and its computation using the Boundary Elements Methods (BEM) under the potential flow theory. This allows one to quickly estimate the ship resistance in various configurations.

(4) Use of numerical simulation in viscous fluid (by solving the Navier-Stokes equations) for naval applications:
In this part, the knowledge acquired in the numerical hydrodynamics course is applied to the simulation of the ship resistance problem for a viscous fluid flow.

After completing the course, students will be able to:

- Have a clear image on how to analyze the dynamic motion of ships
- Possess the basic knowledge on various types of optimization algorithms, and know how to use the commercial software modeFrontier to carry out optimization tasks with multi-objectives and complex constraints
- Use a potential flow theory-based solver to compute the ship resistance
- Carry out CFD simulations with FVM to accurately calculate the ship resistance and the free-surface flows around the ship

Course contents

Course 1-Introduction to maneuverability

Students discover the basics of maneuverability:

- Computation of hydrodynamic forces on the ship, forces generated by the ship's propeller(s), action of the rudder, etc. The mathematical framework is presented to express the problem in the frame linked to the ship.

Course 2-Maneuverability from the experimental point of view

- Presentation of maneuverability tests at sea (real scale) and in basins (model scale).

Course 3- Maneuverability from a digital point of view

- Presentation of the state of the art in terms of numerical simulation of the maneuverability problem for ships. Numerical modeling of the turning circle manoeuver.

Course 4-Introduction to optimization

- Presentation of two classic optimization methods: the geometric method and the gradient method. Students learn how to use modeFrontier software with simple examples.

Course5-Advanced Optimization

- Presentation of the so-called genetic optimization method. Students use modeFrontier to optimize the shape of a ship's bow bulb to minimize the wave resistance exerted on that ship.

Course 6-Ship resistance with potential flow theory

- Presentation of the problem of ship resistance (ship with a forward speed in calm water) on a physical point of view. The calculation of the ship resistance under the potential flow theory using Boundary Elements Methods (BEM) is then introduced. Students use the REVA solver (developed in the LHEEA lab at Ecole Centrale Nantes) to carry out fast numerical simulations of ship resistance exerted on a model ship.

Course 7-Numerical simulation in real fluid for naval applications

- Students use the Fine-Marine software (solving the Navier-Stokes equations for a viscous fluid) to carry out the numerical simulation of the flow around a ship with forward speed in calm water.

Course material

- V. Bertram, 2000, Practical Ship Hydrodynamics, Butterworth Heinemann.
- T.I. Fossen, 2011, Handbook of marine craft hydrodynamics and motion control, Wiley
- N. Newman, Marine Hydrodynamics
- O.M. Faltinsen, Sea loads on ships and offshore structures
- J.H. Ferziger, M. Peric, Computational Methods for Fluid Dynamics, Springer

Assessment

Collective assessment: EVC (coefficient 0.8)

Individual assessment: EVI 1 (coefficient 0.2)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	8 hrs	4 hrs	18 hrs	0 hrs	2 hrs

YEAR 2 - Autumn Semester

Numerical Hydrodynamics [NUMHY]

LEAD PROFESSOR(S): Lionel GENTAZ

Objectives

The goal of this class is to provide students with an overview of Computational Fluid Dynamics (CFD) methods and the simulation environment for the computation of free-surface unsteady flows in ocean engineering. 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 km^2 to seconds and m^2) of the investigated problems and the engineering objectives (energy conversion quantification, design for standard operation, extreme condition design, multi-objectives optimisation, etc ...). According to the approximations made, different numerical methods can be developed and applied.

The primary objective is that students gain a clear vision of the use of different approximations and methods, and of their respective ranges 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 (BEM: Boundary Element Method, HOS: High-Order Spectral), to a full description of the Navier-Stokes equations (FD: Finite Differences, FV: Finite Volumes) 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 space discretization (structured surface meshes, unstructured volume meshes, meshless, etc.) is detailed. Numerical properties such as convergence, stability, consistency are reviewed.

The links between numerical method and current simulation environment are covered: existing commercial software, human and computational resources, choice of software depending on the targeted problem, link with hardware (High-Performance Computing, cloud resources) etc.

Finally an introduction to multi-objective optimization processes is presented.

Lab works using Navier-Stokes software based on FV numerical methods are proposed to students with the use of a commercial software.

Course contents

Numerical method for potential flows

- Introduction of Boundary Element Methods (BEM), Integral methods solving, Hydrodynamic loading calculation

Numerical methods for viscous flows

- Volume discretization methods (Finite Volumes), Time integration and stability

Introduction to multi-objective optimization

- Presentation of the problem of optimization in engineering.
- Presentation of two typical optimization methods: the geometrical method and the gradient-based method.
- The students learn to write a simple program for carrying out an optimization task minimizing a cost-function.

Navier-Stokes equations solution techniques

- State of the art of CFD in hydrodynamics for Ocean Engineering
- Pressure-velocity coupling, Linear system solving, Volume meshing
- Hydrodynamic loading calculation, Interface methods (VoF, LS)
- Turbulence models (RANS, LES)
- Lab work is dedicated to use of a CFD viscous flow solver for academic cases (lid-driven cavity, turbulent flow over a step …).

Course material

- 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

Assessment

Collective assessment: EVC (coefficient 0.4)

Individual assessment: EVI 1 (coefficient 0.6)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	16 hrs	4 hrs	10 hrs	0 hrs	2 hrs

Research in Marine Hydrodynamics [REMHY]

LEAD PROFESSOR(S): Antoine DUCOIN

Objectives

The objective of this class is to introduce the students to some of the major research in numerical hydrodynamics at the LHEEA research Laboratory of Centrale Nantes. The course is divided into three parts:

LBM (lattice Boltzmann method), Zhe Li

Over the last two decades, the lattice Boltzmann method (LBM) has emerged as a promising numerical tool for simulating, not limited to, various types of fluid flows in nature as well as in engineering applications. It has been recently demonstrated that the LBM can be systematically derived from the Boltzmann equation (kinetic theory). This inherent feature allows the LBM to solve the fluid dynamic problems with a large range of scales.

FSI (Fluid Structure Interaction), Antoine Ducoin

An overview of Fluid Structure Interactions (FSI) for hydrodynamic applications is presented in this class. The objective is then to be able to understand fundamentals of flow induced vibration for marine applications.

SPH (Smoothed Particle Hydrodynamics), David Le Touzé

The Smoothed Particle Hydrodynamics method is knowing a growing interest for complex free surface flows, mainly when characteristic times are short (impact, slamming, sloshing, spray, etc.). The course covers the various aspects of the method theory and application to marine engineering.

Course contents

LBM (lattice Boltzmann method)

This course consists of six hours of lecture and four hours of programming lab work. The theoretical basis of the LBM is first presented in the lecture, such as the derivation from the Boltzmann equation using Hermite polynomial expansion, the relation with the Navier-Stokes equation via the Chapman-Enskog analysis. The second part of the lecture is devoted to the presentation of the numerical aspects of the LBM, such as the collision and streaming steps, the boundary condition treatment. In the lab work, the students will learn how to write a LBM program using Matlab in order to simulate some academic test-cases, e.g. Poiseuille flow, lid driven cavity. The objective of the lab work is to make the students better understand this numerical method and experience its simplicity of implementation. Finally, a short introduction to recent novel solvers based on the evaluation of finite volume flux with gas kinetic theory and scheme will be given to the students.
6h theory – 4h labworks

FSI (Fluid Structure Interaction)

An overview of Fluid Structure Interactions (FSI) for hydrodynamic applications is presented in this class.
The first part concerns the basic equations for fluid structure interaction problems, followed by a non-dimensional analysis to extract the different classes of fluid structure interactions.
The class then focuses on the particular case of flow induced vibration. Two simple FSI problems are then studied: the free motion of a 2D cylinder under unsteady, periodic flow, and the static deformation of a 2D hydrofoil under stationary flow.

In the third part, an overview of the numerical methods for fluid structure interaction problems is presented.
In the computer lab work, we will study Fluid Structure interaction of a flexible lifting profile by a strong coupling between a CFD code for the fluid and a one degree of freedom system for the structure.
4h theory – 8h labworks

SPH (Smoothed Particle Hydrodynamics)
It is first highlighted the different reasons why this method is well suited to these complex free surface problems (advantages), and why it is also mainly limited to them (drawbacks).
The method theory is then developed and compared to standard mesh-based methods in terms of: schemes of approximation of the differential operators, convergence and accuracy, explicit solving of Navier-Stokes equation, weak-compressibility assumption, quasi-Lagrangian description, etc. Implementation is also discussed, especially in the context of High Performance Computing.
Finally, it is shown how this method is applied to industrial marine engineering problems, and it is discussed what are its current trends of development: improvement of convergence, particle refinement, easy Fluid-Structure Interaction, coupling to Finite Volumes.
A 4h computer lab is given to the students after the lectures on an academic test case.
4h theory – 4h labworks

Course material

Lecture 1 (LBM):

- Shan, X., Yuan, X.F., Chen, H. Kinetic theory representation of hydrodynamics: a way beyond the Navier-Stokes equation. Journal of Fluid Mechanics 550: 413-441, 2006.
- Guo, Z., Zheng, C., Shi, B. Discrete lattice effects on the forcing term in the lattice Boltzmann method. Physical Review E 65: 046308, 2002.
- Succi, S. The lattice Boltzmann equation: for fluid dynamics and beyond. Oxford University Press. 2001

Lecture 2 (FSI)

- M.P. Païdoussis. Fluid-Structure Interactions : Slender Structures and Axial Flow. Academic Press, 2004
- J.F. Sigrist , Fluid-Structure Interaction: An Introduction to Finite Element Coupling, Wiley, 2015

Lecture 3 (SPH):

- D. Le Touzé, 'Smoothed Particle Hydrodynamics, fact checking: from theory to applications', Keynote lecture at the 2017 SPHERIC international workshop, http://spheric-sph.org//files/SPHERIC_Beijing_Keynote_pdf.pdf
- G.R. Liu, M.B. Liu, 'Smoothed Particle Hydrodynamics, a meshfree particle method', World Scientific

Assessment

Collective assessment: EVC (coefficient 0.4)
Individual assessment: EVI 1 (coefficient 0.6)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	12 hrs	0 hrs	18 hrs	0 hrs	2 hrs

YEAR 2 - Autumn Semester

Monitoring strategy and monitoring systems [MONIT]

LEAD PROFESSOR(S): Franck SCHOEFS

Objectives

The course first focuses on why do we need to monitor a structure. Illustrations from a worldwide feedback for harbour structures allow presenting the main stakes. Structural Monitoring strategy embraces a lot of fields: technology of the sensor, physics of the sensor to get a measure useful for the engineers, transmission of information, where to place the sensors, how many, how to decide and how to use the signal.

This course covers all these fields by focusing on three technologies (image processing, resistivity of porous materials and fiber optical sensors) in view to cover all the stakes.

At the end of the course the students will be able to:

- Describe the major families of sensors, their uses and the means of acquisition available.
- Prescribe the performance of measurement, transmission and storage systems according to a specific use.
- Describe the simple physical principles of large families of sensors.

Course contents

This module is composed of two chapters with uneven repartition of times.

Chapter 1 SHM Strategy

- Unit 1: SHM Strategy (5,3 h). This part includes an e-learning section.
- Unit 2: Instrumentation of offshore structures, experience feedback (1.3h)

Chapter 2 Sensors, measurements and measurements analysis for the SHM (25.3 hours)

- Unit 3: Optical techniques for strain and temperature measurement (2.6 h)
- Unit 4: Strain measurement using optical fibers, practical case (4h)
- Unit 5: Parameters identification by analysis of static measurements (6.6 h)
- Unit 6: Field measurement, DIC, VIC, (4h)
- Unit 7: Parameters identification by analysis of dynamics measurements (4h)
- Unit 8: Corrosion measurement and cathodic protection (4h)

Course material

- Courses of the European COST Action TU 1402: https://www.cost-tu1402.eu/

Scientific papers:

- Lanata F., Schoefs F., "Multi-algorithm approach for identification of structural behavior of complex structures under cyclic environmental loading", Structural Health Monitoring (SAGE), 11:1/January 2012, 51-67, doi: 10.1177/1475921710397711 - 2012
- Lecieux Y., Rozière E., Gaillard V., Lupi C., Leduc D., Priou J., Guyard R., Chevreuil M., Schoefs F., "Monitoring of a reinforced concrete wharf using SHM system and material testing", Journal of Marine Science and Engineering, Section Ocean Engineering, Special Issues "Monitoring of Coastal and Offshore Structures", 7(4)/ (April 2019), #84, 1-26, doi:10.3390/jmse7040084– 2019
- On line videos: https://www.youtube.com/watch?v=V_KSJkD7hTk and https://mediaserver.univ-nantes.fr/permalink/v1261a0a2b515wpsns67/

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	16 hrs	8 hrs	8 hrs	0 hrs	2 hrs

YEAR 1 - Spring Semester

Approximation Methods in Computational Mechanics and Probabilistic Methods in Mechanics [APPROB]

LEAD PROFESSORs: Mathilde CHEVREUIL

Objectives

Marine structures are subjected to environmental loading. The latter is fundamentally hard to predict and has an inherent uncertainty. It has been shown progressively since the 1980's that reliability methods develop the most efficient tools in view to design offshore structures by modelling uncertainties (environment as said previously or material, soil) through the probability theory.
That allows to compute or estimate a probability of failure. A failure leads to consequences of various levels depending on the industrial field and the sensitivity of environment: for instance failure of an oil and gaz platform leads to economical costs but also to environmental consequences depending on the distance to shore.
To deal both with the failure and its consequence in presence of uncertainties, concept of risk has been progressively used. It is fundamental for owners, operators or administrations that need to analyze rationally these very complex issues.

This course provides knowledge about 5 topics – Know numerical methods for the approximation of the response of a structure; Understand the concepts of risk, uncertainty, reliability and safety; Know statistical methods for modeling physical, model, statistical and measurement uncertainties; Know methods for the assessment of the reliability of structural systems using probabilistic methods; Know methods for systems reliability for non-structural components and its applications in engineering - in view to reach two key competencies: Be able to participate in a dialog on modelling of uncertainties, risk analysis and assessment of reliability of structural and non-structural components and systems; Be able to model, calculate and communicate risk analysis, modelling of uncertainties and assessment of reliabilities for engineering problems.

At the end of Approximation Methods in Computational Mechanics and Probabilistics in mechanics, the learner will be able to:

(Knowledges) :

- Know approximation methods and dedicated error estimations,
- Understand the concepts of risk, uncertainty, reliability and safety,
- Know statistical methods for modeling physical, model, statistical and measurement uncertainties,
- Know methods for assessment of reliability of structural systems using probabilistic methods,
- Know methods for systems reliability for non-structural components and its applications in engineering,

(Skills) :

- Approximate the response of a system using either the model equations (variational formulations and Finite Element method) or an observation sample set (least-squares method)
- Model physical, statistical, model and measurement uncertainties,
- Use failure rates and hazard functions to model failures in systems reliability for non-structural components,
- Model uncertainties for loads and strengths,
- Estimate the reliability by FORM/SORM methods (reliability index method) and by simulation,
- Model system behavior and estimate the reliability of series and parallel systems,
- Understand basic concepts of stochastic processes and time-variant reliability methods,
- Estimate characteristic and design values for strength parameters and load bearing capacities, and for environmental loads and load effects using test data and measurements,
- Calibrate partial safety factors and load combination factors,
- Apply Bayesian statistical methods,
- Apply risk and reliability methods for probabilistic design of engineering structures such as buildings, bridges, offshore structures, costal structures, wind turbines etc.,
- Use correct professional terminology,

(Competencies) :

- Participate in a dialog on modelling of uncertainties, risk analysis and assessment of reliability of structural and non-structural components and systems,
- Model, calculate and communicate risk analysis, modelling of uncertainties and assessment of reliabilities for engineering problems.

Course contents

This module is composed of 14 units. Except for the units 7 and 14, the units are organized as below:

- a part dedicated to face-to-face on campus courses and tutorials classes on approximation methods.
- a part dedicated to the viewing of videos and the reading of documents in semi-autonomy proposed on the e-learning platform by Pr.John Dalsgaard SøRENSEN on Risk and Reliability. This part includes self-assessment activities like quizzes and the possibility to ask questions related to the module to your instructors via the online forum.
- a part dedicated to face-to-face on campus tutorials classes on Risk and Reliability with Pr. Franck SCHOEFS.

You will also work on a mini-project tutored by Pr. Franck SCHOEFS.

The module includes:

- Approximation method based on an observation sample set
- Approximation method based on variational formulation
- Introduction and Uncertainty modelling
- Uncertainty modelling
- Reliability of components
- Structural reliability 1
- Structural reliability 2: reliability of components
- Partial Safety Factors
- Load combination problems
- Risk analysis
- Examples

Course material

- This module includes mainly videos, PDF of the videos slides and notes.

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	20 hrs	20 hrs	6 hrs	0 hrs	2 hrs

Metamodeling and Uncertainty Quantification [MUQUANT]

LEAD PROFESSOR(S): Valentine REY

Objectives

This course is an introduction to machine learning: the role of surrogate modeling in engineering design optimization, inverse problems or uncertainty quantification is presented and the basic concepts for its construction based on observations are introduced.

At the end of the course the students will be able to:
- classify supervised or unsupervised learning methods,
- describe and select model classes,
- construct a regression or classification model approximation based on observed data,
- validate the approximation,
- use the model approximation as a surrogate model (also known as metamodel),
- post-process the surrogate model for uncertainty quantification and reliability purposes.

Course contents

The lectures will cover the following:
- Design of experiment
- Classical parametrized model classes: neural networks, polynomial chaos, gaussian process, support vector machine, reduced order models
- Learning methods
- Validation metrics and techniques for error estimation

Tutorial and homework sessions will allow the students to practice and construct metamodels on benchmarks or data bases. The students will also work on a mini-project that will use metamodeling for risk and reliability analysis.

Course material

- The elements of Statistical learning, H. Friedman, R. Tibshirani and T. Hastie, Springer, 2009
- Model Reduction and Approximation: Theory and Algorithms, P. Benner, A. Cohen, M. Ohlberger and K Willcox, SIAM, 2017
- Neural networks and deep leaning, M. A. Nielson, 2015

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	5	16 hrs	0 hrs	16 hrs	0 hrs	2 hrs

Cultural and Communication English [CCE3]

LEAD PROFESSOR(S): David TROYA

Objectives

Team-building and Communicational English:

- Understand the general concepts of team-building
- Build a team-building project
- Understand and nurture the creative process
- Enhance self-belief and self-empowerment

Behavioral skills in an inter-cultural environment:

- Strengthen self-confidence and capacity for interaction
- Develop active listening and reformulation skills
- Develop networking skills

Course contents

Cultural and Communicational English: exercises to explore in practice the areas of culture and communication

Field-related or inter-cultural project (for example, construct content for inter-cultural teambuilding activities; example WIOBOX website etc).

Course material

Written and televised press, information and digital tools, general documents business environment and company strategies. Internet conferences (Ted Talks, etc.), our own educational materials on Hippocampus (Moodle).

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	2	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

YEAR 2 - Autumn Semester

Spanish Language [ESP3]

LEAD PROFESSOR(S): Marta HERRERA

Objectives

For beginners:

- Practice and reinforcement of the five skills (oral and written expression and comprehension as well as interaction) - - Acquisition of vocabulary and linguistic structures
- Be able to talk about yourself and those around you Be able to express oneself during daily activities Know how to give your opinion

For advanced students:

- Practice and reinforcement of the five skills (oral and written expression and comprehension as well as interaction) Acquisition of specialised vocabulary
- Be able to understand the essential content of concrete or abstract subjects including a technical discussion Be able to communicate spontaneously and fluently
- Be able to express oneself in a clear and detailed manner, to express an opinion on a topical subject

Course contents

For beginners:

- Personal environment (introduce yourself, express yourself, your tastes, your character, your hobbies, etc.), your surroundings (friends, family, location, climate), your interests (sports, leisure)
- Present tense (regular and irregular)
- Language patterns to express habit, obligation, "gustar" and its equivalents, Possessive adjectives
- Differences between "es", "está", "hay" Use of "por" and "para"
- Adverbs and frequency patterns Numeral adjectives

For advanced students:

- Knowledge of the Hispanic world (economic, technical, cultural and social environment) Present tense (regular and irregular)
- Imperative Past tenses
- Direct / indirect style Future tense Conditional tense
- Present and past subjunctive moods

Course material

Preparation manuals, our own tailor-made documents, written and internet press, general civilization documents, digital tools

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
Spanish	2	0 hrs	16 hrs	0 hrs	0 hrs	0 hrs

French Language [FLE3]

LEAD PROFESSOR(S): Silvia ERTL

Objectives

The objective is to familiarize the learner with the French language and French culture through an entertaining task-based communicative language teaching, focused on speaking combined with:

- Phonetics
- Self-correcting exercises on our learning platform
- Learning Lab activities
- Project work
- Tutoring

Course objectives include the acquisition and reinforcement of vocabulary, syntax, and pronunciation by both traditional means and through the use of digital resources. Students will learn general French, develop language skills of oral and written comprehension and expression.

After completing this course (32 hours + personal work), the students will be able to communicate in spoken and written French, in a simple, but clear manner, on familiar topics in the context of study, hobbies etc. Another important goal of this course is to introduce the student to French culture.

At the end of the course, complete beginners can achieve an A1 level and some aspects of the A2 of The Common European Framework of Reference for Languages. More advanced students may aim for B1/B2 levels. Those who already completed the first year of the French course will be prepared for working in a French business environment.

Course contents

Two different tracks are proposed: track 1 for students newly arrived at Centrale Nantes and track 2 for students who have completed the first year of the French course. Track 1:

Full range of practical communication language exercises: reading comprehension, listening comprehension, written expression, oral expression.

Learners will be able to use the foreign language in a simple way for the following purposes:

1. Giving and obtaining factual information:

- Personal information (e.g. name, address, place of origin, date of birth, education, occupation)
- Non-personal information (e.g. about places and how to get there, time of day, various facilities and services, rules and regulations, opening hours, where and what to eat, etc.)

2. Establishing and maintaining social and professional contacts, particularly:

- Meeting people and making acquaintances
- Extending invitations and reacting to being invited
- Proposing/arranging a course of action
- Exchanging information, views, feelings, wishes, concerning matters of common interest, particularly those relating to personal life and circumstances, living conditions and environment, educational/occupational activities and interests, leisure activities and social life

3. Carrying out certain transactions:

- Making arrangements (planning, tickets, reservations, etc.) for travel, accommodation, appointments, leisure activities
- Making purchases
- Ordering food and drink

Track 2:

This track follows on directly from the first-year French course, developing and completing the concepts studied thus far. The main themes are: housing, health and work. These topics will help prepare students for their future work environment. For example, housing is explored in the form of a search for accommodation upon arrival in a new city. Special workshops for CVs and cover letters, elevator pitches and job interviews.

Course material

Preparation manuals, our own tailor-made documents, written and televised press, internet, general civilization documents, digital tools, our own educational materials on Hippocampus (Moodle).

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
French	2	0 hrs	16 hrs	0 hrs	0 hrs	0 hrs

YEAR 2 - Spring Semester

Internship / Thesis project [THESIS]

LEAD PROFESSOR(S): Guillaume DUCROZET

Objectives

- Be exposed to and adapt to an industrial or research environment
- Put in practice the scientific and technical skills acquired in the previous semesters
- Strengthen interpersonal and communication skills
- Be part of or manage a project
- Organize tasks, analyze results and build deliverables

Course contents

Students should be pro-active and career-oriented in the search for their thesis/internship. The topics are validated by the program supervisor to ensure an adequate Master level. The thesis/internship is evaluated through the submission of a written report and an oral defense.

Course material

- Turabian Kate Larimore, Booth Wayne Clayton, Colomb Gregory G., Williams Joseph M., & University of Chicago press. (2013). A manual for writers of research papers, theses, and dissertations: Chicago style for students and researchers (8th edition.). Chicago (Ill.) London: University of Chicago Press.
- Bui Yvonne N. How to Write a Master's Thesis. 2nd ed. Thousand Oaks, Calif: Sage, 2014.
- Evans David G., Gruba Paul, et Zobel Justin. How to Write a Better Thesis. 3rd edition. Carlton South, Vic: Melbourne University Press, 2011.

Assessment

Individual assessment: EVI 1 (coefficient 1)

Language of instruction	ECTS Credits	Lectures	Tutorials	Lab	Project	Exam
English	30	0 hrs	0 hrs	0 hrs	0 hrs	0 hrs