*EMSHIP$^{+}$ : Advanced Design of Ships and Offshore Structures"*

[WWW.EMSHIP.EU](http://WWW.EMSHIP.EU)

# Academic year 2020-2021 (3rd and 4th M120 cohorts)

*All the lectures of the EMSHIP programme are in English*

**First Year (Master 1): S1 and S2 (at ULiège)**

MASTER MECA - Finalité spécialisée (ULiège): ***Advanced Ship Design***

LECTURES in MECHANICS (30 credits)

➔ ***EMSHIP Specialisation***

| COMPUTATIONAL MECHANICS | xxx | **Advanced Ship Design** |
|---|---|---|
| 30 credits (including an "integrated project" of 15 credits) | 30 credits (including an "integrated project" of 15 credits) | 30 credits (including a specific Integrated Project of 15 credits) |

**Second Year (Master 2 – M2) : S3 and S4**
**Organised at ECN, URO, UPM in the framework of double degrees (or joint degree for UPM) with ULiège**

| COMPUTATIONAL MECHANICS *(organised at ULiege)* | xxx *(organised at ULiege)* | **Advanced Ship Design** *(Organised at ECN, URO, UPM)* |
|---|---|---|
| 60 credits | 60 credits | 60 credits **(see details here after)** |

# MASTER 1 – at ULiège

## 1 ULiège LECTURES of the "MECHANICAL ENGINEERING" MASTER
(ULiège – Master 1 - 30 credits)

**Mandatory courses – Common core** – 30 credits

| | |
|---|---|
| *MECA0444 Manufacturing Process* | 5 credits |
| *MECA0029 Theory of vibration* | 5 credits |
| *MECA0462 Materials Selection* | 5 credits |
| *GEST3162 Principles of Management* | 5 credits |

and **10 credits to take in block "Computational Mechanics" (*)**

*which includes:*

| | |
|---|---|
| *MECA0036 Finite Element Method* | 5 credits **(recommended)** |
| MECA0027 Structural and Multidisciplinary Optimization | 5 credits **(recommended)** |
| *MECA0031 Kinematics and dynamics of mechanisms* | 5 credits |
| *MECA0023 Advanced solid mechanics* | 5 credits |
| *MECA0010 Stochastic modelling* | 5 credits |

(*) *Preferential choices for students of the **"ADVANCED DESIGN OF SHIPS AND OFFSHORE STRUCTURES"** specialization are underlined.*

## 2 EMSHIP LECTURES – at ULiège – Master 1 (30 credits)

➔ **Advanced Ship Design – EMSHIP** (30 Credits)

**Master 1 – Semester 2 (30 credits) - given at ULiège**
ULiège SPECIALISATION in "Advanced Ship Design" (30 credits)

| **Compulsory courses** | | | Credits |
|---|---|---|---|
| CNAV0012-2 | **Integrated Design Project of Ships, Small Crafts and High Speed vessels**<br>Including initiation to Ship Theory, Ship Structure, Ship propulsion and Ship production | HAGE – RIGO | 15 |
| CNAV0013-2 | **Ship Theory: Statics and Dynamics** | HAGE A.,<br>RIGO Ph. | 5 |
| CNAV0014-2 | **Ship and Offshore Structures**<br><br>Including also:<br>- Ship Production, Welding,...<br>- Planning and logistics<br>- Composite Material (Marine applications) | RIGO Ph,<br>COURARD L<br>CAPRACE JD | 7 |
| CNAV0016-2 | **Ship Equipment and Propulsion Systems** | HAGE A.<br>and<br>NGENDAKUMANA Ph. | 3 |

# MASTER 2: Lectures at an EMSHIP Partner (full year, 60 credits)

## URO-Rostock; ECN-Nantes; or UPM-Madrid

Semesters S3 and S4 (60 credits) will be organised by **ONE EMSHIP university** (and may be combined with a third mobility done in the framework of the standard Erasmus student exchanges program).

Semester 3 (30 credits) is organized at Rostock (Ship Technology – Ocean Engineering), Nantes (topic: Marine Hydrodynamics), or Madrid (Offshore Wind and Renewable Marine Energy), in the framework of the double degrees (Join degree with UPM) organized for the EMSHIP ERASMUS MUNDUS Master course.

In annex (pages 7-62), a detailed content of these lectures is given.

Semester 4 (30 credits) is a semester with a free mobility and is dedicated to

- URO: the Master thesis with industrial support (30 credits)
- ECN : the Master thesis with industrial support (30 credits)
- UPM : the Master thesis with industrial support (30 credits)

**SEMESTER S3 (Sept – Jan) : Advanced lectures**

Mandatory Lectures (30 Credits):

S3 is organised at ECN (Fr), URO (Rostock), or UPM (Madrid);
each university having his own "Advanced" speciality.

The students have the choice between:
- Nantes (ECN, France): Marine Hydrodynamics (30 credits)
- Rostock (URO, Germany): Ship Technology – Ocean Engineering (30 credits)
- Madrid (UPM, Spain): Offshore Wind and Renewable Marine Energy (30 credits)

Each of these 4 universities will deliver a degree as ULiège (double degree).
So, four (4) double degrees have been signed:

- ULiège - ECN
- ULiège - URO
- ULiège - UPM

**SEMESTER S4 (Feb – June/Sept): Master Thesis and Internship (30 Credits)**

Master thesis (25 credits) at least 3 months
Internship (5 credits) at least 2 months, which can be achieved during S3, S4 or S3 & S4.

S3 and S4 are formally under the responsibility of ECN (Fr), URO (Rostock) or UPM (Spain) as only these Universities deliver a double degree (or join degree) with ULiège.

But, instead of staying in ECN, URO, or UPM during S4, students can also perform a third mobility at:

- Galati (UGAL, Romania): Manoeuvring and Propulsion
- Szczecin (ZUT, Poland) Advanced Ship and Offshore Structures
- Nantes (ICAM, France) : Composites Manufacturing and Offshore Wind Turbine
- Southampton (SOLENT, UK) Yacht Design
- La Spezia (UNIGE, Italy) Yacht structures

and
- UFRJ (Rio, Brazil), PUSAN (Korea), OSAKA(Japan), MICHIGAN(USA), UNSW (Australia) and ITU (Turkey) universities,

keeping in mind that the full responsibility and control remain the duty of ECN, URO or UPM.

---

# Proposed coding scheme for EMship$^+$ lectures.

| | | |
|---|---|---|
| EMSHIP$^+$_M1-ULiège-1, | EMSHIP$^+$_M1-ULiège-2, | etc. |
| EMSHIP$^+$_M2-ECN-1, | EMSHIP$^+$_M2-ECN-2, | etc |
| EMSHIP$^+$_M2-URO-1, | EMSHIP$^+$_M2-URO-2, | etc |
| EMSHIP$^+$_M2-UPM-1, | EMSHIP$^+$_M2-UPM-2, | etc. |

# TABLE OF CONTENT, OUTCOMES AND PREREQUISITES

# OF THE LECTURES

Part 1: M1 at ULiège – Fundamental lectures

Part 2: M1 at ULiège - Naval Architecture

Part 3a : Master 2 at ECN
Part 3b : Master 2 at URO
Part 3c : Master 2 at UPM

# Part 1: M1 at ULiège – Fundamental lectures

## MASTER PROGRAM IN MECHANICAL ENGINEERING (EMSHIP),

https://www.programmes.uliege.be/cocoon/20192020/en/programmes/A2UMEC02_C.html#cycle_MECA0018-2

## ULIÈGE – MASTER 1 - BLOC 1 : 30 CREDITS OF FUNDAMENTAL LECTURES

**Mandatory courses – 20 credits**

*MECA0018 Manufacturing processes (Marchal Y)* 5 credits
http://progcours.ulg.ac.be/cocoon/cours/MECA0018-2.html
MECA0029 *Theory of vibration* 5 credits
http://progcours.ulg.ac.be/cocoon/en/cours/MECA0029-1.html
*MECA0462 Materials Selection* (Ruffoni Davide) 5 credits
http://progcours.ulg.ac.be/cocoon/en/cours/MECA0462-2.html
*GEST3162 Principles of Management* (M Ghilissen et al) 5 credits
http://progcours.ulg.ac.be/cocoon/en/cours/GEST3162-1.html

**Elective courses to take in the block "Computational Mechanics" – 10 credits (*)**

*Courses to be chosen among the following list (*)*

MECA0036 *Finite Element Method* 5 credits **(recommended)**
http://progcours.ulg.ac.be/cocoon/en/cours/MECA0036-2.html
MECA0027 *Structural and Multidisciplinary Optimization* 5 credits **(recommended)**
www.programmes.uliege.be/cocoon/en/cours/MECA0018-2.html
MECA0031 *Kinematics and dynamics of mechanisms* 5 credits
http://progcours.ulg.ac.be/cocoon/en/cours/MECA0031-2.html
MECA0023 *Advanced solid mechanics* 5 credits
http://progcours.ulg.ac.be/cocoon/en/cours/MECA0023-1.html
MECA0010 *Stochastic modelling* 5 credits
http://progcours.ulg.ac.be/cocoon/en/cours/MECA0010-1.html

(*) Preferential choices for students of the **"ADVANCED SHIP DESIGN"** specialisation are underlined.

**Track – "Advanced Ship Design" Specialisation - 30 Credits**

*Integrated design project of ships, small crafts and high speed vessels* 15 cr
https://www.programmes.uliege.be/cocoon/en/cours/APRI0009-1.html

*Ship Theory : Statics and Dynamics* 5 cr
http://progcours.ulg.ac.be/cocoon/en/cours/CNAV0013-2.html
*Ship & Offshore structures* 7 cr
http://progcours.ulg.ac.be/cocoon/en/cours/CNAV0014-2.html
*Ship equipment & propulsion Systems* 3 cr
http://progcours.ulg.ac.be/cocoon/en/cours/CNAV0016-2.html

**Pre-requisites of the EMSHIP programme:**

- *Fundamental branches: Mathematics, Physics, Applied thermodynamics , Heat transfer, Mechanics, Chemistry and Numerical Methods*
- *Physics of materials, 5 cr (or equivalent)*
- *Mechanics of materials, 5 cr (or equivalent)*
  http://progcours.ulg.ac.be/cocoon/en/cours/MECA0001-2.html *(see details below (*) )*
- Solid mechanics, *5 cr (or equivalent)*
  http://progcours.ulg.ac.be/cocoon/en/cours/MECA0012-6.html *(see details below (**) )*
- *Fluid mechanics, 5 cr, (or equivalent)*
  http://progcours.ulg.ac.be/cocoon/en/cours/MECA0025-3.html *(see details below (***) )*
- *Dynamics of Mechanical systems, 5 cr, (or equivalent) - (see detail below ****)*
  *https://www.programmes.uliege.be/cocoon/en/cours/MECA0155-2.html*
- *Experience in programming, Finite Element Method Programing code and CAD*
  - *Programming (coding), using for instance MATLAB, $C^{++}$, Python, ...)*
  - *Finite Element Method : appreciated but not mandatory*
  - *CAD tool is highly relevant (but not mandatory)*

**(*) *Solid mechanics***

http://progcours.ulg.ac.be/cocoon/en/cours/MECA0001-2.html

Overview and structure of the course

- General equilibrium principles (identification of all external efforts acting on the studied body, concept of the cut and identification of the internal forces acting on both sides of the cut)
- Notions of stresses and of plasticity surfaces (Mohr circle in in-plane stress field)
- Material properties: link between the stresses and the deformations
- Beam definition
- Calculation of internal forces in a structure constituted of beams (MNT diagrams)
- Calculation of internal forces in a truss
- Security concepts
- Study of the different internal forces in a beam section - how to pass from forces to stresses (tension, compression, bending, torsion, shear, combined loading)
- Deflections in structures made of beams
- Concept of second order analysis and notions of elastic buckling of beams in compression

**(**) *Mechanics of materials***

http://progcours.ulg.ac.be/cocoon/en/cours/MECA0012-6.html

General overview: This course provides the basic knowledge in Solid Mechanics: concept of stress tensor, strain tensor, material's constitutive law, Hooke's law, deformation energy and link with thermodynamics, virtual work principle and energy theorems, isotropic linear elasticity theory. These concepts are then applied to various practical cases: thick tubes under pressure, pressurized sphere, force on an infinite medium, contact between two elastic solids, torsion of prismatic solids, tensile and bending of prismatic solids, corner shaped solids, stress concentration...

The topics of the course are: * Introduction to tensorial calculus and index notation. Application to the statics: stress tensor, balance equations... * Kinematics: strain in 1D, rigid body motion, tensoriel definition, F=RU, Green strain tensor, volumic strain, Cauchy strain tensor, Saint-Venant compatibility equations * Virtual work principle + energy theorems (Engesser, Castigliano...) * 3D Hooke's law, material mechanical properties, additivity rule, strain energy, uniqueness of the solution * Fundamental equations of linear elasticity (Navier's equations and Beltrami-Michell's equations) * 3D elastic problems: pressurized tubes, pressurized sphere, Kelvin's problem, Boussinesq's problem, Hertz contact problem * Torsion of general prismatic solid: Prandtl's function, warping of the sections... * 2D elastic problems: Airy's function, applications in cartesian coordinates (tensile and bending of prismatic solids) * 2D elastic problems: applications in polar coordinates (bending of a curved beam, corner shaped solids, plate with a hole, stress concentration) * Fatigue: introduction to the concept of fatigue, origin of fatigue failure, Wöhler curves, number of cycle to failure, endurance limit

(***) *Fluid mechanics*
http://progcours.ulg.ac.be/cocoon/en/cours/MECA0025-3.html

**Course contents :**
The course provides a rigorous and systematic presentation of the basic concepts and classical mathematical models used in various fields of application of Newtonian fluid mechanics. These models, and their simplified versions, are used to better understand the underlying physical processes.
The following topics are addressed:

- Kinematics of fluid flows.
- Budget equations (local and integral forms) and associated boundary conditions. Newtonian fluid and Navier-Stokes equations.
- Vorticity dynamics and potential flow.
- Similitude theory and flow regimes.
- Introduction to gas dynamics : rule of forbidden signals in supersonic flows, shock waves.
- Turbulence : characterization, RANS simulations, Taylor theory of turbulent dispersion.
- Gravity waves, capillarity waves, internal waves. Kelvin-Helmoltz instability.

**Learning outcomes of the course :**
At the end of the course, the student will master the basic concept of Newtonian fluid dynamics. He/She will be able to use both the tensor and indicial formalism to design mathematical models of most large scale and small scale flows. In particular, he/she will be able to make the link between the physical processes and their mathematical parameterization and to justify the main assumptions.
He/She will be able to write down budget equations, understand the processes responsible for the transport of information and energy in fluids, use integral forms of the Navier-Stokes equation to describe simple flows. He/She will also be able to rely on a simplified 1D model to describe shock waves in a nozzle.
Through the group project, the course contributes to the development of soft skills like self-study, collaborative work and reporting.

(****) **Dynamics of Mechanical Systems**

http://progcours.ulg.ac.be/cocoon/en/cours/MECA0155-2.html

**Course contents**

The course provides the fundamentals of the dynamics of mechanical systems. Course outline

- Review of Lagrangian and Newtonian dynamics and application to simple mechanical systems.
- Single and multiple degrees-of-freedom systems: fundamentals (resonance frequency and mode-shape), response prediction to forced excitations.
- Continuous systems and discretisation methods.
- Dynamic behavior of rotating machines: critical speeds, balancing methods.

The theoretical concepts will be illustrated through hands-on exercises and vibration experiments performed in the classroom. One project will be assigned during the course semester.

**Learning outcomes of the course:**

The objective is to give to the students a solid background in the modelling and the simulation of the dynamical behavior of mechanical structures. Typical vibration problems encountered in mechanical systems and rotating machines will illustrate the theory.

**Prerequisites :**

This course requires basic knowledge of fundamental calculus, differential equations and applied mechanics.

| Title: **MANUFACTURING PROCESS** | 5 credits |
|---|---|
| Ref: ULiège: MECA0018<br>Prof : MARCHAL Y | EMSHIP+_M1-ULiège-1<br>Teaching Period: S2 - Feb- May |
| Link : [www.programmes.uliege.be/cocoon/en/cours/MECA0018-2.html](www.programmes.uliege.be/cocoon/en/cours/MECA0018-2.html) | |

**Course contents**

This course is devoted to manufacturing processes, with and without chips. It is a necessary complement to design, as any designed machine element has to be produced.

Table of content:

Elementary discussion on steel production. Steel classification, following EURONORM and SAE/AISI. Casting, forging, stamping, wire-drawing, extrusion, sheet metal working. Welding, soldering, oxygen-cutting. Elements of powder metallurgy. Metal cutting. Grinding. Lapping, honing, superfinishing, polishing. Unconventional processes: ultrasonic grinding, chemical engraving, electrochemical machining, electro-discharge machining, electron beam, laser machining, water jet machining, plasma cutting. Cutting theory: Piispanen-Merchant model, cutting temperature. Cutting angles, cutting power, tool wear. Tool materials. Roughness prediction. Chip control. Milling: down and up milling, power evaluation. Grinding: equivalent thickness, power consumption, grinding ratio, roughness prediction.

**Learning outcomes of the course**

After this course, the student will be able to conceive a pertinent manufacturing process of a mechanical part. He will also be able to conceive mechanical parts which are easy to produce and thus cheap.

**Prerequisites :**

General mechanics, first bases of strength of materials.

| Title: **THEORY OF VIBRATION** | 5 credits |
|---|---|
| Ref: ULiège: MECA0018<br>Prof : JC GOLINVAL | EMSHIP+_M1-ULiège-1<br>Teaching Period: S2 – Sept-Jan |
| Link : [http://progcours.ulg.ac.be/cocoon/en/cours/MECA0029-1.html](http://progcours.ulg.ac.be/cocoon/en/cours/MECA0029-1.html) | |

**Course contents**

This course provides a solid background in vibration theory for engineering applications.

Course outline

- Introduction and analytical dynamics of discrete systems
- Undamped vibrations of n-degree-of-freedom systems
- Damped vibrations of n-degree-of-freedom systems
- Continuous systems: bars, beams and plates
- Approximation of continuous systems by displacement methods; Rayleigh-Ritz and finite element method
- Solution methods for the eigenvalue problem
- Direct time-integration methods
- Introduction to nonlinear dynamics

One project will be assigned to the students. It will give hands-on practice with methods used in structural dynamics (e.g., the finite element method, Newmark's algorithm, component mode synthesis).

**Learning outcomes of the course**
The objective of the course is to focus on analytical and computational methods for predicting the dynamic response of **practical engineering structures**. Special attention is devoted to aerospace, mechanical and civil engineering structures.

**Prerequisites :**
This course requires basic knowledge of fundamental calculus and differential equations. The course also requires a mastery of introductory dynamics and mechanics.

**Assessment methods and criteria**
The final grade will be based on the project report and a written exam:
1. The project has to be done individually or by group of maximum 2 students. The grade will be based on the results and the quality of the report (scientific and technical content, conciseness, structuring of the written report and clarity of the text). An oral presentation will be organised at the end of the project.
2. The written exam will consist in answering to questions on the theoretical concepts explained during the lectures. No document is allowed for the written exam.
The assessment is based on the weighted geometric average of the project and the written exam.
The final note is calculated as follows: Final note = (Project)^(0.6) * (Theory)^(0.4)
There is no partial exemption in case of failure.

Title: **MATERIALS SELECTION** 5 credits

Ref (ULiège): MECA0462-2 EMSHIP+_M1-ULiège-3
Prof : RUFFONI Davide Teaching Period: Sept-Jan

Link : http://progcours.ulg.ac.be/cocoon/en/cours/MECA0462-2.html

**Course contents**
Description and use of different types of materials: metals, ceramics, polymers, composites and biological materials. Origin and optimisation of mechanical and physical properties of materials. Selection of the optimal material in function of the required mechanical and/or physical properties. Concept of selection of materials for a typical application (high temperature, optical property,..). Practical cases of materials selection.

**Learning outcomes of the course**
To choose the best material required by a particular application or for particular properties

**Prerequisites :**
Physics of materials (as PHYS0904 - at ULiège)

| Title: **Principles of Management** 5 credits<br><br>Ref (ULiège): GEST3162-1 EMSHIP+_M1-ULiège-6<br>Prof.:M. GHILISEN, Teaching Period: Sept-Dec |
|---|
| Link : http://progcours.ulg.ac.be/cocoon/en/cours/GEST3162-1.html |
| **Course contents**<br>This course introduces the four main dimensions of company management:<br>• Strategy and marketing<br>• Human resources and company organisation<br>• Accounting and financial analysis<br>• Supply chain management" |
| **Learning outcomes of the course** |
| **Prerequisites :**<br>None |

| Title: ***Structural and Multidisciplinary Optimization*** 5 credits<br><br>Ref (ULiège): MECA0027-1 EMSHIP+_M1-ULiège-2<br>Prof : P Duysinx Teaching Period: Sept-Jan |
|---|
| Link : https://www.programmes.uliege.be/cocoon/en/cours/MECA0027-1.html |
| **Course contents**<br>The primary objective of the course is to present a systematic and critical overview of the various numerical methods available to solve optimization problems.<br>A second important goal is to familiarize participants with the introduction of optimization concepts into the design process in aerospace or in mechanical engineering. The basic concepts are illustrated throughout the course by solving simple optimization problems. In addition, several examples of application to real-life design problems are offered to demonstrate the high level of efficiency attained in modern numerical optimization methods. Although most examples are taken in the field of structural optimization, using finite element modeling and analysis, the same principles and methods can be easily applied to other design problems arising in various engineering disciplines such as structural engineering, electromagnetics systems or multidisciplinary optimization.<br><br>• Optimization in Engineering Design<br>• Fundamentals of structural optimization<br>• Introduction to Mathematical Programming<br>• Algorithms for Unconstrained Optimization: Gradient Methods<br>• Line Search Techniques<br>• Algorithms for Unconstrained Optimization: Newton and Quasi-Newton Methods<br>• Quasi-Unconstrained Optimization<br>• Linearly Constrained Minimization<br>• General Constrained Optimization: Dual Methods<br>• General Constrained Optimization: Transformation Methods<br>• From Optimality Criteria (OC) to Sequential Convex Programmming<br>• Structural approximations<br>• CONLIN and MMA<br>• Sensitivity Analysis for Finite Element Model |

- Introduction to shape optimization
- Introduction to topology optimization

**Learning outcomes of the course:**
At the end of the course the participants will be familiar with the fundamental optimization concepts applied to automatic design process.
They will be able:

- to develop solution schemes to simple engineering optimization problems related to design or parameter identification (including the development of computer program written in MATLAB language),
- to choose efficient formulations and optimization algorithms to solve their own problems using commercial tools,
- to read, understand and take advantage of scientific papers from the field,
- to get started with using an industrial optimization software tool (NX-TOPOL)

**Prerequisites :**
Bachelor in Engineering, Functional analysis of real functions, Matrix algebra, Matlab programming (basic level)

Title: **Finite Element Method** 5 credits

Ref (ULiège): MECA0036-2 EMSHIP+_M1-ULiège-4
Prof : J-Ph Ponthot Teaching Period: Feb-June (S2)

Link : http://progcours.ulg.ac.be/cocoon/en/cours/MECA0036-2.html

**Course contents**
The goal of this course is to learn develop both theoretical concepts as well as practical use of the method. Starting from the mechanical behavior of simple structures like pin jointed structures; fundamental concepts of the structural analysis are introduced. Subsequently, it is shown how the general elastic equations established in continuum mechanics can be discretized and how it is possible to obtain an approximate solution for these equations.

**Learning outcomes of the course**
Being able to :

- Understand the fundamental theory of the finite elements
- Develop skills to model the behavior of elastic structures
- Use a commercial finite element software for structural analysis

**Prerequisites :**
Mechanics of materials.

# Part 2: M1 at ULiège - Naval Architecture

## LIST OF LECTURES (Naval Architecture) in M1, at ULiège, 30 credits

Title: **INTEGRATED DESIGN PROJECT OF SHIPS, SMALL CRAFTS and HIGH SPEED VESSELS** 15 credits

Ref (ULiège): *APRI-0009-1* EMSHIP+_M1-ULiège-7
Prof : A Hage, Ph Rigo Teaching Period: Sept-June

Link : https://www.programmes.uliege.be/cocoon/en/cours/APRI0009-1.html

**Course contents:**
The lecture "INTEGRATED DESIGN PROJECT OF SHIPS, SMALL CRAFTS and HIGH SPEED VESSELS" includes initiation to Ship Theory, Ship Structure, Ship propulsion and Ship production.
Running an integrated project: Introduction to the role of naval architecture in ship design, definition of the main steps of a project "Ship loop" and the development of the project.
General characteristics: definition of the main dimensions (lengths, surfaces, volumes ...), weight estimates and displacement, definition of coefficients in relation to speed and geometrical characteristics of the hull, adjusting dimensions for good seaworthiness and stability.
Introduction to Ship Theory (Statics):
Ship geometry and hydrostatics: Ship measures (Lpp, …), Form coefficients, Bonjean curves, Methods of integration to define the hydrostatics curves, Center of Gravity (CG) and Principles of transverse stability.
Propulsion: Flow Resistance estimation, dimensioning of the propulsion system (engines, propellers, rudder, gearboxes,..). Resistance estimation, practical rules of dimensioning the propulsion system (engines, propellers, rudder, gearboxes,..). On-board energy: electrical overview and organization of the distribution of energy. Protection against corrosion. Insulation (thermic, fire, acoustic).
Project coherence and final checks.
Ship types and hull forms definition: Displacement, semi-planning and planning hull, multihull, SWATH, SLICE and boats with outriggers. Comparison of pros and cons: resistance, seaworthiness, and performance at sea, maneuverability, and structural resistance. Recommendations for design of multi-hull boats.
Introduction to Ship structures: Description of ship structure (transversal, longitudinal and mixed system), ship types (tankers, LNG, containers, passenger ships, multi-hulls ...). Components of ship structure (longitudinal stiffeners, frames, simple hull, double hull, bow and stern, motor zone, ...). Basic structural solid mechanics (bending moment, shear forces, torsion, ..): primary bending (hull girder), secondary components (frames) and tertiary components (plates, stiffeners,...). Design Criterions.
Use of CAO (2D, 3D) tools and CAE in ship design. Design software for ship design: Maxsurf, Lunais, Shipconstructor, Argos. Digital simulations and calculations: CFD (Fine Marine), EF: SAMCEF. Virtual reality. Virtual business project. Exchange of technical data.
Regulatory approach (classification societies): BV, ABS, Lloyd's, ... Applications complying with the scantling procedures of a classification society. International regulation bodies: IMO, IACS, SOLAS. Classification, monitoring and inspection for maritime and inland navigation vessels. Environment: protection against pollution « MARPOL ».
Design of small crafts and high speed vessels:
Design principle of small boats and fast boats.

| |
|---|
| Hydrodynamics of semi-planning hulls and planning-hulls: speed coefficients, lift-coefficients,... Definitions of fast boat shapes: developable shape, chine shape, ... Dynamic stability. Types of propulsions: water jet, outboard, Z-drive. Practical design aspects.<br>Towing tank experiments :<br>After completion of his ship design, each group of students will prepare a model (scale) of the designed ship (model of about 1.5 - 2 m) and will test it in the towing tank. |
| **Learning outcomes of the course**<br>This course will result in a presentation of a comprehensive (integrated) ship project where all the naval architecture problematic is considered. |
| **Prerequisites:**<br>Students must have a Bachelor degree in Engineering, with a specialty in civil engineering, mechanical engineering, aerospace engineering, naval architecture, marine or offshore engineering or similar. |

| |
|---|
| Title: **SHIP THEORY – STATICS and DYNAMICS** 5 credits<br><br>Ref (ULiège): CNAV0021-1 EMSHIP+_M1-ULiège-8<br>Prof : A Hage Teaching Period: Sept - June |
| Link : http://progcours.ulg.ac.be/cocoon/en/cours/CNAV0021-1.html |
| **Course contents:**<br><br>This course prepares students to master the basic notions about behavior of ship and offshore structures.<br>The course is mainly composed of lectures with examples and case studies. It first concerns the problems relating to the static and dynamic stability of floating structures.<br>Statics: Assessment of the center of gravity (CG), addition/removal/transfer of mass, effect of a suspended mass, principles of transverse stability, heeling moments and free surface effect, elementary principles of trim, the inclining experiment, loading conditions and rules, preparation of the intact stability booklet, and ship partially afloat.<br>Dynamics: Review of wave theories (regular and irregular waves), Vibrations and Damping, Heaving, Added mass for a Ship, Rolling in Calm Water, Rolling in waves, Powering in a seaway, Effect of design variables on Seakeeping.<br>A significant part of the course is devoted to manual practical work and computer-based work. Tests on models in a towing tank will also be carried out. |
| **Learning outcomes of the course:**<br><br>This course is part of the Advanced Master's Degree in Ships and Offshore Structures (EMSHIP - WWW.EMSHIP.EU ). It prepares students to master the basic notions relating to the behaviour of floating and naval structures. |
| **Prerequisites :**<br>Students must have a Bachelor degree in Engineering, with a specialty in civil engineering, mechanical engineering, aerospace engineering, naval architecture, marine or offshore engineering or similar. |

Title: **SHIP and OFFSHORE STRUCTURES** 7 credits

Ref (ULiège): CNAV0014-3 EMSHIP+_M1-ULiège-9
Prof : P Rigo; L Courard, JD Caprace Teaching Period: Sept -June

Link : http://progcours.ulg.ac.be/cocoon/en/cours/CNAV0014-3.html

**Course contents**
This lecture includes several parts and an introduction to ship structure design and analysis is given in the lecture "**Integrated design project".**

1) FUNDAMENTALS OF SHIP and OFFSHORE STRUCTURES
Criterions of dimensioning, Design limit states, Rational approaches (direct calculation) of sizing (scantling) versus rules based approaches, Modern tools for modeling; Structural analysis (FEA); Optimisation, .... An important part of the course includes practical exercises (weekly).

2) ULTIMATE STRENGTH, RELIABILITITY ANALYSYS, FATIGUE, VIBRATION, OPTIMISATION - Description of the various limit states (service, ultimate, accident, ..) of the ship structure (yielding, buckling and tripping of beams, buckling and ultimate strength of plates and stiffened plates, ultimate bending moment of hull girder, fatigue (curves S-N), vibration, collision & grounding, ...). Ultimate strength of hull girder: simplified approach, curvature - bending moment curve and average stress and strain curve of the components (progressive collapse analysis, Smith method), non-linear analysis, fluid-structure interaction .... - Vibrations: theory of vibrations (basic notions); technology aspects: Cause of vibrations in ship structures; Techniques of measurement, control and prevention techniques; practical impact on design. - Structure reliability concepts (loads and strength) in calculation of structures (rule based approaches and direct calculations). - Materials (steel, aluminium, composite materials, sandwich panels, ...). - Introduction to ship structure optimization (least cost, least weight, ...).

3) SHIPYARDS & SHIP PRODUCTION - Shipyard layout (organisation, implantation, functions, shipyard types, etc.) - Planning and logistics - Economical context. - Shipyard production processes. - Main steps of shipbuilding production (sequences, material flows, etc.). - Modular construction (blocks, sections, etc.). - Main workshops in shipyards (machining, cutting, bending, forming, panel line, outfitting, straightening, etc.). - Welding and cutting processes (welding types, welding processes, welds control, weld calculation). - Launching methods (dry dock, slipway, etc.) - Modern tools for production simulation and cost assessment - Concurrent Engineering tools such as Design for Production, Lean manufacturing, Quality Management, etc. - Scheduling notions (Potential and Pert methods)

4) COMPOSITE MATERIALS (Marine application)
The lecture objective is to give relevant knowledge and practical expertise to perform a ship design using composite materials.
Description of mechanical performances of fibers (glass, carbon, Kevlar, bore, silicium...) and resins (Polyester, Epoxy, PUR). Comparison with metallic materials. Advantages of composite materials. Description of composites: isotropic, anisotropic, tubes and reservoirs, sandwich, multilayers, laminated. Models for composite materials. Simplified methods for properties assessment. Manufacturing methods (experimental test in lab – done by students).

- Discussion on the structural responses for isotropic, orthotropic and anisotropic materials.
- Structural applications of metallic and non-metallic composite structures in shipbuilding industry.
- Description of elastic behaviour in composite structure.

- Structural failure modes/theories translated to ship structures.
- Application of the Class rules and/or FEM tools for structural design.

**Learning outcomes of the course:**
The main objective is to give a general overview of the structural problems that must be considered at the conceptual design stage, early design stage and detailed design stage.
The lecture focuses on the first principle design methods and relies on rational approaches. It surveys the various limit states that must be considered for the structural design and scantling assessment.
Concerning Shipyards: The objective is the understanding of production technologies and manufacturing methods for shipbuilding industry in order to integrate production limits at the design stage (Design for production)

**Prerequisites :**
Good knowledge in structure mechanics.
Typically students must have a Bachelor degree in Engineering, with a specialty in civil engineering, mechanical engineering , aerospace engineering, naval architecture, marine or offshore engineering or similar.

Title: **SHIP EQUIPEMENT and PROPULSION SYSTEMS** 3 credits

Ref (ULiège): CNAV0022-1 EMSHIP+_M1-ULiège-10
Prof : Hage A., Ph Ngendakumana Teaching Period: Feb-June

Link : http://progcours.ulg.ac.be/cocoon/en/cours/CNAV0022-1.html

**Course contents**
1) Equipment and on-board electricity: On-board electricity: different types of distribution networks, electrical circuit protection, cables. Energy production: calculation of installed power, general characteristics of alternators, engines, dynamos, creating parallel connections. Energy users: classes of user, equipment installed below bridge, equipment installed on the bridge. Electric and turbo-electric diesel propellers. Classification regulations.
2) Propulsion Systems for naval and commercial vessels. Presentation of the different types of Marine Propulsion systems, advantages and disadvantages.
3) Marine diesel engines: Operating and performance parameters. Description of different types of engines. Engine power (ISO 3046). Overheating. Injection and combustion. Engines powered by heavy fuel. Emissions and reduction of pollutants.

**Learning outcomes of the course**
The main objective is to give a general overview of the definition of the outfitting problem (including the propulsion aspects) that has a large influence at the conceptual design stage.

**Prerequisites :**
Students must have a Bachelor degree in Engineering, with a specialty in civil engineering, mechanical engineering , aerospace engineering, naval architecture, marine or offshore engineering or similar.

# Part 3a: Master 2 at ECN

# Hydrodynamics for Ocean Engineering

Courses proposed here are dedicated to Hydrodynamics for ships and offshore structures. That means mathematical models, numerical or experimental methods which are used to study and evaluate performance, hydrodynamic loads, motions of all floating structures, used for maritime transport, production of energy on seas …

## LIST OF LECTURES - M2 at ECN

The 60 credits at ECN are composed of:

- 30 ECTS lectures during the 3rd semester
- 30 ECTS Master Thesis (integrated with the Internship) during the 4th semester

The Master Thesis can be performed at ECN or in other labs and companies in France or abroad.

## SEMESTER 3 : Lectures (30 credits)

| EMSHIP+ | SUBJECT NAME | CREDITS |
|---|---|---|
| M2-ECN-0 | PREREQUISITES<br>**(to be obtained at ULiège or before)**<br>• Fluid Mechanics<br>• Mathematics for Engineers | 0 |
| M2-ECN-1 | GENERAL CONCEPTS OF HYDRODYNAMICS | 4 |
| M2-ECN-2 | WATER WAVES AND SEA STATE MODELLING | 4 |
| M2-ECN-3 | WAVE-STRUCTURE INTERACTIONS | 4 |
| M2-ECN-4 | NUMERICAL HYDRODYNAMICS | 5 |
| M2-ECN-5 | EXPERIMENTAL HYDRODYNAMICS | 4 |
| M2-ECN-6 | NAVAL ENGINEERING<br>• Ship Manoeuvrability<br>• Multi-objective optimization<br>• CFD tools for ship simulation | 5 |
| M2-ECN-7 | FRENCH LANGUAGE | 4 |

**<u>SEMESTER 4: MASTER THESIS (30 credits)</u>**

| **Course code** | **Course title** | **ECTS credits** |
|---|---|---|
| M2-ECN-8 | Master Thesis and Internship | 30 |

The Master thesis is formally under the responsibility of ECN, as ECN delivers his Master specialised in Hydrodynamics for Ocean Engineering ($2^{nd}$ year Master) at the end of the program.

Students can perform their Master thesis in ECN, in a university laboratory, in a private company, in a research centre in France or abroad.

Students can also perform their Master thesis in one of the partners of the EMSHIP consortium.

In all cases, the topic of the Master thesis must be in relation to Free Surface Hydrodynamics and Ocean Engineering and has to be validated by ECN.

The duration of the Master Thesis is six months. Students must write a Master Thesis report and defend their work at the end of their Master Thesis; this defence is organized by ECN.

**ECN Teaching team**

The ECN teaching team involved in the EMSHIP+ program will be composed initially by :

- Sandrine AUBRUN, professor
- Félicien BONNEFOY, Associate Professor
- Antoine DUCOIN, Associate Professor
- Guillaume DUCROZET, Associate Professor
- Silvia ERTL, Associate Professor
- Pierre FERRANT, Professor (*)
- Lionel GENTAZ, Associate Professor (Contact person for the EMSHIP+master)
- Alban LEROYER, Associate Professor
- David LE TOUZE, Professor
- Zhe LI, Associate Professor

(*) authorization to lead PhD Thesis in France)

Others members of the Laboratory of Research in Hydrodynamics, Energetics and Atmospheric Environment (LHEEA) in ECN or people from other institutions (universities, laboratories, companies) will possibly contribute to the lectures given by ECN.

| |
|---|
| Title: **PREREQUISITES** 0 Credit<br><br>Ref : EMSHIP+_M2-ECN-0<br>**Prof : S. AUBRUN** **Teaching Period: Sem 3** |
| Link : |
| **Course contents**<br><br>**1) Objectives**<br>To remind basics of Fluid mechanics and mathematics which are essential for a good understanding of all courses of the semester<br><br>**2) Content**<br>**Fluid mechanics**<br>- Continuous media<br>- Navier-Stokes equations<br>- Dimensional analysis<br>- Kinematics<br>- Calculation of stresses<br>**Mathematics for engineers**<br>short introduction to Matlab computer language with practical classroom |
| **Learning outcomes of the course**<br>To be comfortable with basics of Fluid Mechanics and Mathematics for Engineers |
| **Prerequisites** |

| |
|---|
| Title: **GENERAL CONCEPTS OF HYDRODYNAMICS** 4 Credits<br><br>Ref : EMSHIP+_M2-ECN-1<br>**Prof :** P. FERRANT, L. GENTAZ, D. LE TOUZE **Teaching Period: Sem 3** |
| Link : |
| **Course contents**<br><br>**1) Objectives**<br>The objectives of this course are to give a general overview to students about use of Hydrodynamics in marine and ocean engineering fields, about modelling and physics of free surface flows, numerical simulation in Hydrodynamics, hydrostatic and stability of floating structures. This global overview will be latter detailed in other courses of the Master program.<br><br>**2) Content**<br>**Industrial, R&D and research activities connected to free surface hydrodynamics and ocean engineering**<br>A state of the art of problems of engineering or applied research where use of Hydrodynamics is required<br><br>**Different classes of approximation used in Hydrodynamics**<br>Presentation of different mathematical models which can be used in Hydrodynamics to describe free surface incompressible free surface flows (Navier-Stokes equations, Euler equations, Laminar and turbulent boundary layer equations, Potential flow model) and main problems of free surface Hydrodynamics for which each model is adapted |

**Introduction to Numerical Simulation**
Following parts will be described :
- Methodology for numerical simulation of a physical problem
- Implementation of a numerical method
- Pre- and post-treatment
- High-performance computing

**Hydrostatic and Stability of ships and marine structures**
Intact and damaged stability of floating structures are investigated through theoretical and practical aspects. Computer lab work is done with state of art industry software. This part is done by a naval architect from a design company located in Nantes.

**3) Recommended Reading**
- J.N. Newman, *Marine Hydrodynamics*, The MIT press, 1977
- V. Bertram, *Practical Ship hydrodynamics*, Elsevier, 2012 (2nd Edition)
- A.J. Hermans, *Water Waves and Ship Hydrodynamics: An Introduction*, Springer, 2010 (2nd Edition)
- Biran, *Ship Hydrostatics and Stability*, Butterworth-Heinemann, 2003

## Learning outcomes of the course
To know how Hydrodynamics is used today in naval and offshore engineering
To be able to define what mathematical model is adapted to a given problem in Hydrodynamics
To know fundamental aspects of numerical simulation in Hydrodynamics.
To know main parameters used to evaluate hydrostatic stability of a floating body

## Prerequisites
Basics of fluid mechanics

Title: **WATER WAVES AND SEA STATES MODELLING** 4 credits

Ref : EMSHIP+_M2-ECN-2
**Prof :** G. DUCROZET, F. BONNEFOY **Teaching Period: Sem 3**

Link :

## Course contents

**1) Objectives**
This course intends to describe the main source of loading for structures at sea (e.g. marine renewable energy systems), namely ocean waves. This is essential for the design of such structures and is the starting point of all hydrodynamics' studies (see courses: wave-structure interactions, experimental hydrodynamics, marine renewable energy, etc.).
First we give an overview of some of the numerous mathematical models used to represent free surface gravity waves, and the associated underlying flow. 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.
In the second part, the use of the statistical approach is presented, both for the representation of sea states and for the sea structure's response.

**2) Contents**
**Introduction to marine environment**
Description of the ocean and the different kind of waves existing. Focus on the gravity waves and the processes responsible for their generation.
*2h theory*
**Gravity waves modelling**

Derivation of the governing non-linear equations and introduction of the multiple scale method to generate particular subset of equations.
*2h theory*
**Dispersive waves**
a) 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.
b) Higher order Stokes solutions (3rd order, 5th order). Sequential construction of the Stokes higher order solutions. Specific nonlinear features of Stokes waves.
c) Stream function model. Explanation of the method – numerical application
*4h theory + 2h practical classroom + 4h computer*
**From deep water to shallow water**
a) Refraction and shoaling of dispersive waves
b) Shallow-water (non-dispersive) waves
   i) Derivation of Boussinesq equation.
   ii) The solitary wave as a particular solution of Boussinesq equation.
   iii) KdV equations: cnoidal waves.
*2h theory*
**Statistical models for wave field description**
a) Random sea state modeling.
b) Usual wave spectra models.
c) Wave generation
*4h theory + 2h practical classroom + 6h computer*
**Random responses of structures at sea**
a) Random responses of a linear system.
b) Review of the results for ship responses by a deterministic theory.
c) Motions on a real sea state.
d) Extreme responses, design factors.
*4h theory + 4h computer*
**3) Recommended Reading**
- 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*

## Learning outcomes of the course
What are hypothesis used to defined different wave models which can be found in literature or in marine engineering community ?
To be able to calculate and use main parameters of a irregular wave state

## Prerequisites
Basics of fluid mechanics (Navier-Stokes equations, potential flow model, free surface conditions), General concepts of hydrodynamics

Title: **WAVE-STRUCTURE INTERACTIONS** and MOORINGS 4 credits

Ref (ECN): EMSHIP+_M2-ECN-3
**Prof :** P. FERRANT **Teaching Period: Sem 3**

Link :

## Course contents
**1) Objectives**

The objective of the first part is to give a complete presentation of the available models for the determination of marine structures 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 second order effects 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 modelling 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. This part is teach by an engineer specialized in moorings and working in offshore industry.
For both parts lectures and seminars are completed by practical exercises based on state of the art software for wave-structure interaction and mooring modelling.

**2) Contents**

**Objectives, theoretical framework**
*1h theory*
**Short review of linear systems theory**
*1h theory*
**Formulation of the boundary value problem. Linearization**
*2h theory*
**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

*4h theory + 2h tutorial + 8h practical classroom*
**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

*2h theory*
**Second order effects**

a) Drift forces
b) Low and high frequency loading in irregular waves

*2h theory*
**Introduction to nonlinear models**

a) Nonlinear hydrostatics and Froude-Krylov loading
b) Weak scattered hypothesis
c) Fully nonlinear models

*2h seminar*
**Moorings for marine structure**

a) Some examples in Oil and Gas energy
b) Different types of mooring systems
c) Offloading operations
d) Some examples in Marine Renewable energy
e) Mooring main functions
f) Mooring arrangement
g) Mooring components
h) Environmental conditions
i) Mooring Design basis

*4h theory + 8h computer lab*

**3) Recommended Reading**

- 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 Stationkeeping Systems for Floating Structures*.
- Vryhof anchors (2010) *Anchor Manual, The Guide to Anchoring*.

**Learning outcomes of the course**
To know hypothesis and limitations of seakeeping study done with a linearized potential flow model; To be able to calculate and use basic results (added mass, radiation damping, excitation forces, drift, RAOs) obtained with a software simulating seakeeping in potential flow theory and frequency domain approach

**Prerequisites :**
Elements on water waves modeling given in the "Water Waves and Sea States Modelling" lecture described before will be useful here.

Title: **NUMERICAL HYDRODYNAMICS** 5 credits

Ref : EMSHIP+_M2-ECN-4
**Prof :** D. LE TOUZE, L. GENTAZ, Z. LI **Teaching Period: sem 3**

**Link :**

## Course contents

**1) 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.

**2) Contents**
**Knowledge and understanding of potential flow solvers**
Potential flow methods (BEM), Integral methods solving, Surfacic meshing, Hydrodynamic loading calculation

*4h theory + 2h tutorials*

**Numerical methods for free surface flows**

Volumic discretization methods (FD, FV), Time integration and stability, Interface methods (VoF, LS), Turbulence models (RANS, LES)

*4h theory + 2h tutorials*

**Navier-Stokes equations solution techniques**

Pressure-velocity coupling, Linear system solving, Volumic meshing

Hydrodynamic loading calculation

*4h theory + 2h tutorials + 14h computer lab work*

**3) Recommended Reading**

- Proceedings of the ONR (Office on Naval Research) conferences
- Proceedings of ITTC conferences on numerical methods and recent developments in numerics
- 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. Nicols, *Turbulence Models and Their Application to Complex Flows*, Univ. Alabama, 2012
- V. Bertram, *Practical Ship Hydrodynamics,* Elsevier, 2012

**Learning outcomes of the course**

To know different numerical methods which are existing, their capacities and their limitations and drawbacks.

**Prerequisites :**

Basics of Fluid mechanics and numerical analysis

Title: **EXPERIMENTAL HYDRODYNAMICS** 4 credits

Ref : EMSHIP+_M2-ECN-5

**Prof :F. BONNEFOY** **Teaching Period: sem 3**

Link :

## Course contents

**1) Objectives**

To provide students with state of the art knowledge on experimental fluid dynamics in the field of Offshore renewable energy. Despite the development of numerical modelling, the experimental approach remains a major source of knowledge development in ship hydrodynamics and marine renewable energy. The contribution to the selection of adequate hypothesis 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 fast way to validate new designs. Specific instrumentations and facilities are presented in this course and used in lab work.

Describe the experimental approaches used in Marine Renewable Energy studies. Involve the students into experimental campaigns in Ecole Centrale Nantes large scale facilities.

Direct applications of the concepts introduced in Water waves and sea states modelling course (environmental modelling), Wave-structure interactions course (structure response, diffraction-radiation, sea-keeping) and Moorings course (low-frequency response, mooring stiffness).

**2) Contents**

**Introduction to experimental hydrodynamics**

The students find the main topics in MRE experiments. Static vs perturbation approaches are presented.

*2h theory + 1h visit of ECN experimental facilities*

**Experimental ocean engineering**

Experimental tests in offshore basins.

*3h theory + 8h practical classroom*
**Resistance**
Ship resistance and experiments in towing tanks. Reynolds and Froude similitude; extrapolation at full scale.
*2h theory + 4h practical classroom*
**Ship manoeuvrability**
Mathematical formulation, experimental determination of hydrodynamic coefficients. Modelling of towed structures.
*2h theory + 4h practical classroom*
**Measurements and signal processing**
Sensors and transducers, sampling theory. Signal processing, Fourier analysis.
*2h theory + 4h practical classroom*

**3) Recommended Readings**

- 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 modeling*

**Learning outcomes of the course**
The purpose is to give elements to students about capacities in experimental hydrodynamics, what phenomena can be studied, what measurements can be obtained …

**Prerequisites :**
Water Waves and Sea States Modelling
Wave-Structure interactions
Numerical Hydrodynamics

Title: **NAVAL ENGINEERING** 5 credits

Ref : EMSHIP+_M2-ECN-6
**Prof : Z. LI, F. BONNEFOY, A. LEROYER** **Teaching Period: sem 3**

Link :

**Course contents**

**1) Objectives**
This course is divided into three main parts, which are all oriented towards fundamental knowledge about ship design. The students learn about ship manoeuvrability, optimization and computational fluid dynamics.

- Introduction of the concepts required for ship manoeuvrability studies.
- Description and practice of the principal scientific methods and tools in optimization for naval architects and ship designers.
- Application of CFD tools to ship simulation

Direct applications of the concepts introduced in Numerical hydrodynamics and Wave-structure interactions course.

**2) Contents**
In manoeuvrability, the students learn how to use the mathematical formulation and the analytical resolution of the linearized problem in simple examples such as turning circles. Realistic configurations are latter studied by means of numerical simulations of the nonlinear problem.

In optimization, the multi-objective approach is used through various examples in naval applications. Different algorithms are presented (gradient, genetic…) and the Mode-Frontier software is applied to optimize the bulb of a ship in order to minimize the wave resistance.
In CFD, the knowledge seen in the Numerical hydrodynamics course is applied to the simulation of a ship with forward speed.

More precisely lectures are organized following description given below :

**Manoeuvrability, an introduction**

The students discover the basics of manoeuvrability: hydrodynamic loads on the hull, propeller loads, rudder action… The mathematical framework is presented to express the problem in the ship reference frame.

*2h theory + 4 h tutorials*

**Experimental manoeuvrability**

Experimental tests at seas (full scale) and in basins (model scale).

*2h theory*

**Computational manoeuvrability**

Presentation of the state of the art in terms of numerical computations of manoeuvring performance of ships

Numerical modelling of turning circle problem

*2h theory + 4h computer classroom*

**Optimization – basics**.

Presentation of two typical optimization methods: the geometrical method and the gradient-based method. The students learn how to use the state of art industry software ModeFrontier with some simple examples.

*2h theory + 4h computer classroom*

**Optimization – advanced**

Presentation of the genetic optimization method. The students will use ModeFrontier to optimize the shape of the bulbous bow in order to minimize the resistance exerted to the ship.

*2h theory + 6h computer classroom on ship resistance and bulb optimization*

**CFD**

The students use the state of art industry software Fine-Marine (solving Navier-Stokes equations for a viscous flow) to build a simulation of a practical case of a ship advancing in calm water

*4h computer classroom on ship resistance*

**3) Recommended reading :**


- 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


## Learning outcomes of the course

To know theory and principles of numerical modelling for the problem of manoeuvrability
To be able to use an optimization software for a practical case of hull optimization
To be able to use a viscous flow CFD software for a practical case of calculation of the drag of a ship advancing in calm water

**Prerequisites :** All courses attended previously during the semester at ECN

| | |
|---|---|
| Title: **FRENCH LANGUAGE** | 4 credits |
| Ref : EMSHIP+_M2-ECN-7<br>**Prof : S. ERTL** | **Teaching Period: sem 3** |
| Link : | |

**Course contents**

**1) Objectives**

The objective is to familiarise 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 pedagogical platform
- Learning Lab activities
- Project work
- Tutoring

Course objectives include the acquisition and reinforcement of vocabulary, syntax, and pronunciation by both traditional means and with the use of digital resources.

Allow students to learn general french, develop language skills of oral and written comprehension and expression.

**2) Contents**

***Giving and obtaining factual information***

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

***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, parti those relating to
  - personal life and circumstances
  - living conditions and environment
  - educational/occupational activities and interests
  - leisure activities and social life

***Carrying out certain transactions***

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

**Learning outcomes of the course**

After completing this course, 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 to French culture. At the end of the course, the complete beginners can achieve the level A1 and some aspects of A2 of The Common European Framework of Reference for Languages**.** More advanced students may aim the levels B1/B2.

**Prerequisites :**

# Part 3b : Master 2 at URO

# Ship Technology – Ocean Engineering

**LIST OF LECTURES (in Naval Architecture) in M2 at URO**

## Overall Schedule at University of Rostock

For graduation in EMship+, students have to earn 120 ECTS in total:

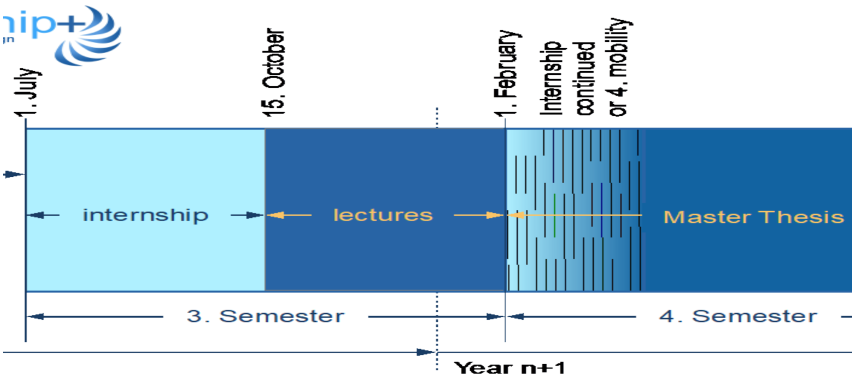


*Figure 1: Schedule of activities in 3. and 4. semester @ URO*

- 60 under the responsibility of University of Liège (master 1 – 1st year – 2 semesters)
- 60 under the responsibility of University of Rostock (master 2 – 2nd year – 2 semesters)

The 60 credits at URO are composed of:

- 24 ECTS lectures – in 3rd semester
- 6 ECTS team project associated with a lecture covering special aspects – in 3rd semester
- 30 ECTS Master Thesis (in cooperation with industry), to be confirmed by the supervisor

Before arrival at URO, students will make up their individual plan (lecture selection) for the 3rd and 4th semesters. This plan has to be approved by a professor at URO assigned responsible for her/his coaching.

Examples of combinations are (all combinations are to be discussed with and approved by the student's coach on an individual basis):

1. for a student seeking a profile in e.g. *Offshore Engineering*:
   URO-1, URO-2, URO-3, URO-6, Master Thesis
2. for a student seeking a profile in e.g. *Ship Technology*:
   URO-2, URO-3, URO-4, URO-5, Master Thesis

## 3rd Semester at University of Rostock – Lectures offered

All lectures are on advanced level and will require the successful pass of the lectures at ULiège in master 1 – 1st and 2nd semesters.

1. **Theory and Design of Floating and Founded Offshore Systems**
   *Lecturer:* Prof. Mathias Paschen
   Module number locally: 1551080
   Module number EMship+: URO-3-1
   Credit points: 6 ECTS

2. **Selected Topics of the Analysis of Marine Structures**
   *Lecturer:* Prof. Patrick Kaeding
   Module number locally: 1551190
   Module number EMship+: URO-3-2
   Credit points: 6 ECTS

3. **Mathematical Models in Ship Theory**
   *Lecturer:* Prof. Nikolai Kornev
   Module number locally: 1551360
   Module number EMship+: URO-3-3
   Credit points: 6 ECTS

4. **IT in Ship Design and Production**
   *Lecturer:* Prof. Robert Bronsart
   Module number locally: 1550940
   Module number EMship+: URO-3-4
   Credit points: 6 ECTS

5. **Safety of Ships under Damaged Conditions, in Waves**
   *Lecturer:* Prof. Robert Bronsart
   Module number locally: 1551230
   Module number EMship+: URO-3-5
   Credit points: 6 ECTS

6. **Ocean Research Technology**
   *Lecturer:* Prof. Mathias Paschen
   Module number locally: 1550870
   Module number EMship+: URO-3-6
   Credit points: 6 ECTS

7. **Team Project**
   *Lecturer:* Prof. Patrick Kaeding and Colleagues
   Module number locally: 1551490
   Module number EMship+: URO-3-7
   Credit points: 6 ECTS

## 4th Semester at University of Rostock – Lectures offered

The Master Thesis is to be worked out in the 4th semester.

It can be performed in close cooperation with industry or “standalone”.

The students can stay at:

- another university of the EMship consortium or an associate university to do the Master Thesis or
- at URO in which case additional lectures can be taken.

In any case, the full responsibility will lie at the University of Rostock, at which URO's supervisor is responsible for the task assignment and the defense, which has to be passed at URO.

**Title: THEORY and DESIGN OF FLOATING AND FOUNDED OFFSHORE SYSTEMS**
**6 credits**

Ref (URO): 1551080 EMship+: M2- URO-1
Prof : Mathias Paschen Teaching Period: October – January

Link : see EMship+ LMS

**Course contents**

1. *Introduction*
   Loads and motions of ships and offshore structures – definition and problems, classification of structures based on hydrodynamic aspects
2. *Marine environment*
   General assumptions, linear wave theory, statistical description of waves, wind, current
3. *Linear wave-induced loads and motions of floating structures*
   Regular and irregular waves, Froude-Krylov-force, added mass, damping forces, Morrison's equation, resonance frequency, transfer function, amplification factor, motion analysis in time and frequency domain, exercises
4. *Numerical methods for prediction of linear wave-induced loads and motions of hydrodynamically compact floating structures*
   2- and 3-dimensional source techniques
5. *Introductions into non-linear problems*
   Applications and exercises
6. *Loads due to current and wind*
   Stationary circulation of circular cylinders and slender bodies with smooth as well as structured surface, laboratory tests
7. *Station keeping of floating systems*

**Learning outcomes of the course**
Students acquire general knowledge about offshore structures for oil and gas exploration and production, for marine aquaculture as well as for underwater applications. In particular, the students learn to recognize the interaction between environmental conditions and particular structures. Students will lay their scientific focus on wave induced loads and motions of floating, submerged or founded offshore structures. They make themselves familiar with methods in linear and non-linear mathematical modelling as well as in experimental methods. They are qualified to elect the most suited methods regarding the respective technical task as well as to apply these methods for hydrodynamic analyses of offshore structures. Students are highly enabled to evaluate and to synthesis results of theoretical and experimental analysis

**Prerequisites :**
Students have to prove knowledge in vector analysis, differential equations, potential and viscous flow as well as basic experience in the field of experimental work.

**Title: SELECTED TOPICS OF THE ANALYSIS OF MARINE STRUCTURES**
**6 credits**

Ref (URO): 1551190 EMship+: M2- URO-2
Prof : Patrick Kaeding Teaching Period: October – January

Link : http://m120.emship.eu/2nd-year-2nd-alternative-rostock#selectedtopicsofmarine ; www.lsk.uni-rostock.de/en/education/lectures-master/selected-topics-of-the-analysis-of-marine-structures/

**Course contents**

1. Introduction to the Analysis and Design of Marine Structures
2. Theory of Shear Force Application
3. Warping Torsion Theory
4. Elastic Foundation
5. Response Spectrum Analysis
6. Beam Element Formulation
7. Newton-Raphson Schemes
8. Arc-Length Method
9. Ultimate Strength

**Learning outcomes of the course**

Students will understand the fundamentals of different methods to analyse marine structures and to judge upon its structural behaviour. The theory of shear force application and the warping torsion theory will be introduces especially for thin-walled closed frame structures. The knowledge of the fundamentals is very important to perform structural analyses of marine structures efficiently. It is also the basis to improve structural systems or to develop new design variants. The students will apply the Finite Element Method (FEM) as a feasible tool to analyse various structural systems. Different element types will be introduced and its applicability will be investigated. To perform nonlinear Finite Element Analyses (FEA) successfully the knowledge of appropriate solution methods is very imported. In frame of this course different solution methods implemented commonly in finite element software packages will be presented. Finally, the students will develop a more comprehensive understanding to perform structural analyses of complex systems.

**Prerequisites :**

Knowledge in “Fundamentals of the analysis of marine structures”, “Finite element method”, “Ship design”, “Ship structural design” or similar

| **Title: MATHEMATICAL MODELS IN SHIP THEORY** **6 credits**<br><br>Ref (URO): 1551360 EMship+: M2- URO-3<br>**Prof : Nikolai Kornev** Teaching Period: October – January |
|---|
| Link :<br>http://bookboon.com/de/lectures-on-ship-manoeuvrability-ebook |
| **Course contents**<br>Differential equation of motion of arbitrary objects in different media. Equations of ship manoeuvring. Determination of added mass. Steady manoeuvring forces. Calculation of steady manoeuvring forces using slender body theory. Forces on ship rudders. Yaw stability. Manoeuvrability Diagram. Experimental study of the manoeuvrability. Influence of different factors on the manoeuvrability. Application of CFD for manoeuvrability problems. Dynamics of offshore structures.<br>More detailed information on course content can be taken from the textbook "Lectures on ship manoeuvrability" which can be downloaded from http://bookboon.com/de/lectures-on-ship-manoeuvrability-ebook |
| **Learning outcomes of the course**<br>The main objective is to give a general overview of mathematical models used in ship dynamics, ship maneuverability and offshore structures dynamics. Having successfully completed the module, the student will be able to demonstrate knowledge and understanding of ship and offshore structures motion at different operational conditions. |
| **Prerequisites :**<br>Students must have a Bachelor degree in Engineering. They must have knowledge in mechanical engineering, naval architecture, marine or offshore engineering, aerospace engineering, or similar. |

**Title: IT IN SHIP DESIGN AND PRODUCTION** 6 credits

Ref (URO): 1550940 EMship+: M2- URO-4
Prof : Robert Bronsart Teaching Period: October – January

Link : see EMship+ LMS

**Course contents**

1. Process analysis in ship design, production and operation: identification of roles (partners), tasks, tools and information flows in international ship design and production networks.
2. Fundamental differences between mass production and one-of-a-kind products like ships and offshore structures
3. CA-tools applied in ship design: input to, functions built in, output from, important links into the ship design and production network
4. Process modelling techniques, examples from shipbuilding processes product modelling, focus on different ship product data sets for different views in interdisciplinary tasks to be performed.
5. Modelling and transformation of information to be used in scenarios requiring multiple and different views.
6. Integration strategies, IT tools to support the in-house as well as cross-company co-operation in ship design networks
7. System architecture of selected tools specifically used in ship design.
8. Principles of shape modelling
9. Fundamentals in mathematical modelling of curves and surfaces in computer graphics

**Learning outcomes of the course**

Students will understand the fundamentals and will be able to judge upon the capabilities of IT-tools in ship design and production. They will be able to identify requirements on these software systems based on a sound knowledge of the ship design and operation life cycle. A clear focus in ship one-of-a-kind design and production processes is applied. The understood necessity of an efficient information exchange between partners and tasks involved leads to the knowledge of suitable information exchange methods and tools. Process and product modeling techniques as a prerequisite for a successful information exchange can be applied by the students in specific exchange scenarios of ship product model data.

They will understand how the underlying design principles are implemented and will experience the complexity of naval architectural and ship design software systems. Students will learn how to operate in complex and unpredictable and/or specialized contexts, and will get an overview of the issues governing good practice.

Prerequisites :

1. knowledge about ship hull form modelling to perform this task with professional tools
2. use a class tool to model and define the scantlings of a "midship section" like GL-POSEIDON, DNV-NAUTICUS or the like.
3. performing a longitudinal strength calculation, required to do scantlings

In URO’s program these 3 topics are the real basics on which we built upon in the advanced lectures

Title: **SAFETY OF SHIPS UNDER DAMAGED CONDITIONS, IN WAVES**
6credits

Ref (URO): 1551230 EMship+: M2- URO-5
Prof : Robert Bronsart Teaching Period: October – January

Link : see EMship+ LMS

**Course contents**

1. Ship and offshore structures hydrostatics and stability repetition
2. Lost buoyancy and additional weight methods to calculate the floating condition after a damage
3. Floodable length curve, criteria freeboard and stability
4. Deterministic determination of ship safety: critical discussion of the compartmentalization factor approach
5. Probabilistic approach for a rational analysis of the effect of watertight internal subdivision
6. Rational methods to calculate the risk in case of a damage, statistical damage data by IMO, Harder project
7. Overview of the development of regulation regarding ship safety in damaged conditions, critical discussion of SOLAS
8. safety against capsizing of ships in waves – introduction introducing actual damages
9. upsetting and uprighting moments, GZ-curve and dynamic aspects
10. Roll oscillations, eigenvalue, forced in regular waves
11. Roll oscillations in a real sea state, sea spectra to model a sea state, probabilistic approach to calculate the ship answer based on RAOs
12. parametric roll excitations, Mathieu function: pros and cons
13. Quantitative assessment of safety against capsizing, Blume criterion, polar diagrammes
14. Critical discussion of the IS-Code and different navy codes
15. Discussion of ship accidents due to excessive roll motions, pure loss of stability, broaching, accidental shift of loads and combinations thereof.

**Learning outcomes of the course**

1) Knowledge and understanding

Having successfully completed the module, the student will be able to demonstrate knowledge and understanding of the physics of floating objects like ships and offshore structures taking into account a damaged condition. Ship safety assessment methods will be known for which deterministic and probabilistic approaches can be distinguished. The importance of ship safety aspects in the overall ship design process will be known, consequences will be understood.

2) Intellectual skills

Having successfully completed the module, the student will be able to apply risk based methods in ship design. She/he will be aware of the limitations and deficiencies of deterministic approaches, e.g. as being implemented in the IMO IS-Code. She/he will be able to fundamentally question regulations with respect to their defined goals and methods formulated.

3) Practical skills

Having successfully completed this module, the student will be able to calculate the floating position of a damaged vessel an to evaluate its remaining stability capacities. She/he will be able to perform calculation to check a given ship design against SOLAS requirements.

4) General transferable (key) skills
Having successfully completed the module, the students will be aware of the limitations of deterministic approaches to solve design problems, she/he understands the advantages of probabilistic design methods to reduce risk in the operation of complex technical objects like ships or offshore structures.

**Prerequisites :**
Sound knowledge is required in hydrostatics, basic knowledge in integral and differential calculus, statistics as well as probability calculations.

**Title: OCEAN RESEARCH TECHNOLOGY** **6 credits**

Ref (URO): 1550870 EMship+: M2- URO-6
Prof : Mathias Paschen Teaching Period: October – January

Link : see EMship+ LMS

**Course contents**

**Part I: Prof. Paschen**
***Measurement and sampling procedures and methods in marine science and underwater monitoring***

1. Introduction
2. Selected challenges in marine research and observation
3. Measurement principles and methods
4. Methods for data storage and transfer
5. Sampling methods and procedures
6. Autonomously and manually operated underwater vehicles
7. Research platforms and research vessels

**Part II: PD Dr. Rudorf**
***System theory and life assessment concepts*** (block seminar)

1. Historical outline of the system concept
2. Life cycles
3. Service life curves and their determination
4. Life predictions
5. System theory and ecology
6. Applications in ocean engineering

**Learning outcomes of the course**
Students will be able to recognize and understand relevant issues of in situ – working disciplines of marine sciences. Therefore, they are able to specify essential requirements for underwater equipment, operations incl. principles of action, precisions and main dimensions. Students can evaluate the interactions between both the living object and measuring techniques. They are able to develop optimized concepts for equipment and procedures for special tasks of marine researchers.
In the second part, students will deepen their understanding of structured technical systems in marine science and technology in particular in terms of necessary redundancies. They will be able to predict the utility and life time of system components and systems for marine technologies.

**Prerequisites :**
Basic knowledge is required in hydrodynamics, integral und differential calculus, statistics and material science.

| Title: **TEAM PROJECT** 6 credits<br><br>Ref (URO): 1551490 EMship+: M2- URO-7<br>Prof : Patrick Kaeding and Colleagues Teaching Period: October – January |
|---|
| Link : see EMship+ LMS |
| **Course contents**<br>This module is strictly linked to any course to be taken at URO. Depending on the topics of the selected course, a problem will have to be solved in a team. Students can select the course for the teamwork project according to their preference. |
| **Learning outcomes of the course**<br>Students will experience themselves in a team solving a defined problem in a defined time span. Depending on the course, the teamwork is linked to students that will intensively make use of different computer programs to solve the assigned task or will perform their own programming and experiments. While doing so, students will have a better understanding of the topics taught as they will work on a real world problem.<br>In teamwork students will develop to work effectively with a group as leader or member, they can clarify tasks and make appropriate use of the capacities of group members. They are able to negotiate and handle conflicts with confidence in a project in which the participants contribute with different but integrated software components.<br>Students will be able to demonstrate initiative and originality in problem solving, can act autonomously in planning and implementing tasks at a professional level while making decisions in complex and unpredictable situations. They will develop a comprehensive understanding of techniques and methodologies applicable to their own work. |
| **Prerequisites :**<br>Students have to register in the course, the team project is linked to. |

# Part 3c: Master 2 at UPM

## "Offshore Wind and Renewable Marine Energy"

**LIST OF LECTURES in M2 at UPM**

The main objective is to provide the students a complete expertise on matters necessary for a proper and comprehensive immersion in the different disciplines (technical, economical and management) that includes the design, project development, construction, operation and maintenance of an offshore renewable plant and more specifically an Offshore Wind Farm.

The scope of the Modules has been carefully designed after a complete assessment of the training needs based on major world-class companies already working in offshore renewable energy harnessing, an industry that demands engineers with multi-disciplinary background.

The 60 credits at UPM are composed of:

- 30 ECTS lectures during the 3rd semester
- 30 ECTS Master Thesis (integrated with the Internship) during the 4th semester

The Master Thesis can be undertaken in UPM or in other labs and companies in Spain or abroad.

**SEMESTER 3: Lectures (30 credits)**

| EMSHIP+ | SUBJECT NAME | CREDITS |
|---|---|---|
| M2-UPM-1 | Oceanology | 1.5 |
| M2- UPM -2 | Structural Design of OWT | 8 |
| M2- UPM -3 | Electric Generation and Export Technologies | 5.5 |
| M2- UPM -4 | Manufacturing and Maritime Operations | 7 |
| M2- UPM -5 | Project Operation and Management | 4 |
| M2- UPM -6 | Structural Analysis of Offshore Platforms | 4 |

## SEMESTER 4: MASTER THESIS AND INTERNSHIP (30 credits)

| Course code | Course title | ECTS credits |
|---|---|---|
| M2-UPM-7 | Master Thesis | 25 |
| M2-UPM-8 | Internship in a Company or Laboratory | 5 |

The Master thesis is formally under the responsibility of UPM, as UPM delivers his Master specialized in Marine Renewable Energies harnessing (2nd year Master) at the end of the program.

See info on:
http://www.etsin.upm.es/English/Estudios/Postgrado/Master%E2%80%99s%20Degree%20on%20Marine%20Renewable%20Energies%20Harnessing

Students can perform their Master thesis in UPM, in a university laboratory, in a private company, in a research centre in Spain or abroad.

Students can also perform their Master thesis in one of the partners of the EMSHIP consortium.

In all cases, the topic of the Master thesis must be in relation to Marine Renewable Energy and has to be validated by UPM.

The duration of the Master Thesis is five months. Students must write a Master Thesis report and defend their work at the end of their Master Thesis; this defense is organized by UPM.

### UPM Teaching team

The UPM academic board involved in the EMSHIP+ program will be composed initially by:

- Luis Ramón Núñez Rivas (MAERM Director) UPM / ETSIN
- José Luis Morán González (General Coordinator) - SIEMENS – UPM / ETSIN
- Enrique Tremps Guerra (Academic Secretary) - UPM / ETSIN
- Vicente Negro Valdecantos - UPM / ETSICCP
- Miguel Ángel Herreros Sierra UPM / ETSIN
- Sergio Martínez González - UPM / ETSII
- Juan Moya García - PAT-18 COIN

Title: **OCEANOLOGY** **1.5 credits**

Ref : EMSHIP+_M2-UPM-1
**Prof : L.R. NÚÑEZ** **Teaching Period: sem. 3**

Link :
http://www.etsin.upm.es/English/Estudios/Postgrado/Master%E2%80%99s%20Degree%20on%20Marine%20Renewable%20Energies%20Harnessing
and
https://moodle.upm.es/titulaciones/propias/course/view.php?id=1449

**1) Objectives**

- Understanding the offshore environmental conditions.
- To gain the ability of building the environmental loads in order to properly model and design the structures.
- Energy resource, characterization: waves, currents, wind-wave joint probability, long term descriptions.

**2) Contents**

Offshore environmental conditions

- Wind condition assessment: wind theories and profiles, wind-wave correlation
- Metocean condition assessment: wave theories (shallow and deep waters), current theories and profiles, tidal conditions
- Discussion on marine growth and impact on design of structures
- Discussion on ice and icing

Environmental resources

- Ocean energy resource: wind
- Ocean energy resource: wave, tidal, thermal

**1) Academic staff**

Luis Ramón Núñez Rivas, Course coordinator
José Luis Morán González / Enrique Tremps Guerra / Amable López Piñeiro / Vicente Negro Valdecantos / José Santos López Gutiérrez / Dolores Esteban Pérez

**2) Bibliography**


- Shore Protection Manual. Coastal Engineering Research Center. Vickburg. U.S.A. 1.984.
- Random Seas and design of maritime Structures. Yoshimi Goda. University of Yokohama. Tokio Press. 1.985.
- Water wave mechanics for engineers and scientists. Robert G. Dean and Robert A. Dalrymple. Advanced series on Ocean Engineering. 1.992.
- Nearshore dynamics and coastal processes. Theory, measurement and predictive Models. Horikawa, K. University of Tokyo Press. 1.988.
- Coastal Engineering Manual. Part II. Coastal Hydrodynamics. 2006


**Learning outcomes of the course**

Understanding the offshore environmental conditions
Energy resource, characterization: Waves, currents, wind-waves joint probability, long term descriptions

Title: **STRUCTURAL DESIGN OF OWT**
**8 credits**

Ref : EMSHIP+_M2-UPM-2
**Prof : V. NEGRO** **Teaching Period: sem. 3**

Link :
http://www.etsin.upm.es/English/Estudios/Postgrado/Master%E2%80%99s%20Degree%20on%20Marine%20Renewable%20Energies%20Harnessing
and
https://moodle.upm.es/titulaciones/propias/course/view.php?id=1450

**1) Objectives**

- Understanding site assessment, including dynamics of floating offshore structures, their mooring and their analysis.
- Understanding the design of foundations of fixed OWT, including the comprehension of the structural design principles, integrated design, material technologies, cathodic protection principles and the Certification Process.
- Gaining the knowledge about new technologies: floating support structures, and marine energy converters

**2) Contents**

Site characteristics
- Offshore dynamics (floating OWT)
- Geotechnical engineering of fixed OWT

Design of fixed OWT
- Foundations: fixed structures
- Structural design principles (FEA)
- Integrated design
- Material technologies
- Cathodic protection systems
- Certification process

Floating wind turbinesDesign methodologies for floating wind turbines
- Mooring systems
- Engineering singularities of floating wind turbines
- Other marine energy converters: TECs, WECs, and OTECs
- Discussion on marine growth and impact on design of structures
- Discussion on ice and icing

Exam courses : (2 hours)

**3) Academic staff**

Vicente Negro Valdecantos, course coordinator
Ángel González / José Santos López Gutiérrez / Dolores Esteban Pérez / Ricardo Zamora / Claudio Olalla Marañón / Mario de Vicente / Juan Carlos Suárez Bermejo / Paz Pinilla Cea / Rodrigo Pérez Fernández / Pedro Soria Ruiz / Luis Pérez Rojas

**4) Bibliography**


- Technical standards and recommendations: BSH, DNVGL, IEC, Puertos del Estado,
- Burton, T., Sharpe, D., Jenkins, N., Bossanyi, E., 2001. Wind energy handbook. Technical book. Ed. Wiley.
- Cruz, J., 2008. Ocean wave energy, current status and future perspectives. Technical book. Ed. Springer.

- Kaiser, M.J., Snyder, B.F., 2012. Offshore wind energy cost modeling, Installation and decommissioning. Technical book. Ed. Springer.
- OTEO, 2014. Offshore Renewable Energy current status-future perspectives for Portugal. Technical book. Ed. INEGI.
- USACE. Coastal Engineering Manual.
- USACE. Shore Protection Manual.
- Chella, M.A., Tørum, A., Myrhaug, D., 2012. An Overview of Wave Impact Forces on Offshore Wind Turbine Substructures. Energy Procedia 20, 217-226.
- Esteban, M.D., Couñago, B., López-Gutiérrez, J.S., Negro, V., Vellisco, F., 2015. Gravity based support structures for offshore wind turbine generators: Review of the installation process. Ocean Engineering, 110-A, 281-291.
- Negro, V., López-Gutiérrez, J.S., Esteban, M.D., Alberdi, P., Imaz, M., Serraclara, J.M., 2017. Monopiles in offshore wind: preliminary estimate of main dimensions. Ocean Engineering, 133, 253-261

**Learning outcomes of the course**

- To get the ability to select the foundation typology that fit best for the purpose
- To outline the structural design process
- To be capable of developing a structural model and run the different analysis that can be required during the design of an offshore structure
- To be capable of defining the material that suits best for any situation
- To properly assess the corrosion impact for the full design life of the structure and define the cathodic protection system
- To state the significance of a correct and consistent definition of the framework from the start of the project
- To be capable of defining the different methods for building the soil pile interaction models that can be accessed in technical literature and design standards.

Title: **ELECTRIC GENERATION AND EXPORT TECHNOLOGIES** **5.5 credits**

Ref : EMSHIP+_M2-UPM-3
**Prof : E. TREMPS** **Teaching Period: sem. 3**

Link :
http://www.etsin.upm.es/English/Estudios/Postgrado/Master%E2%80%99s%20Degree%20on%20Marine%20Renewable%20Energies%20Harnessing
and
https://moodle.upm.es/titulaciones/propias/course/view.php?id=1451

**1) Objectives**

- To have a global vision of different Power Take Off (PTO) types
- To identify the basic model for blades power conversion
- To understand the complete WTG's design process. This part will cover from the aero-servo-hidroelastic calculations for obtaining the load assessment to the dimensioning parameters for the main WTG components
- To present a general model of annual energy estimation
- To understand the operation and behavior of different types of generators and their connection to grid
- To understand of operation aspects related to active and reactive power control
- Knowledge about typologies and technologies of array and export cables
- To analyze the diverse possibilities of using the hydrogen produced from marine renewables

**2) Contents**

Offshore energy converters

- Status of development, technologies, trends.
- Fluid Mechanics of Blades. Design methodologies.
- Structural aspects of Blades. Analysis models.
- Gear Box, Brakes and Supports.
- Generators (mechanical aspects)
- Control Actuators (mechanical)
- Wave Converters PTO's
- Wind and TEC PTO's
- Control and Dynamic Behaviour
- Produced Energy

Grid Technology

- PTO electrical components and Elements
- Offshore substations
- Offshore Converters
- Operation aspects
- Array Cables
- Export Cables
- Grid connection to Shore

Advanced storage offshore technologies

- Hydrogen generation offshore
- Uses of stored hydrogen

Exam course: (2 hours)

3) **Academic staff**

Enrique Tremps Guerra, Course coordinator
Amable López Piñeiro / Pedro Soria Ruiz / José Andrés Somolinos Sánchez / Alfonso Martínez Caminero / Juan Miguel Pérez de Andrés / Sergio Martínez González / Carlos Veganzones Nicolás /
Teresa Leo Mena

4) **Bibliography**


- *Electricity from Wave and Tide*. Paul A. Lynn. Wiley (2014)
- *Wind Turbine Control Systems.* Fernando D. Bianchi, Hernán De Battista
- and Ricardo J. Mantz. Springer (2007)
- *Onshore and Offshore Wind Energy*. Paul A. Lynn. Wiley (2012)
- *Biblioteca sobre Ingeniería Energética*. Pedro Fernández Díez. http://es.pfernandezdiez.es/
- *Modelado Energético de Convertidores Primarios para el Aprovechamiento de las Energías Renovables Marinas*. Amable López P. et al. Revista Iberoamericana de Automática e Informática industrial Vol.2 2014. www.elsevier.es/RIAI.
- *Methodologies for Tidal Energy Converters Evaluation Early Project Phases*. L.R. Núñez et al. 1st International Conference on Renewable Energies Offshore RENEW'14. Lisbon 2014
- T. Burton, N. Jenkins, D. Sharpe, E. Bossanyi. *Wind Energy Handbook*
- IEC 61400-1 Ed3. *Design Requirements*
- IEC 61400-3, Ed1. *Design Requirements for Offshore Wind Turbines*
- DNV-OS-J101. *Design of Offshore Wind Turbines*
- GL2010. *Guideline for the Certification of Wind Turbines*
- *Electric Machinery Fundamentals*. Stephen J. Chapman. McGraw Hill (2012)
- *Induction Machines Design Handbook*. Ion Boldea, Syed A. Nasar. CRC Press (2010)
- *Synchronous Generators*. Ion Boldea. CRC Press (2016)
- Stolten D (editor), Samsun R C (editor), Garland N (editor), *Fuel Cells: Data, Facts and Figures,* Wiley, 2016.
- Godula-Jopek A (editor), *Hydrogen Production: by Electrolysis*, Wiley-VCH, 2015.


**Learning outcomes of the course**

- To be capable to make a basic design of rotor and PTO, related with the site characteristics obtaining the energy produced and optimizing the main parameters
- To be capable of developing a structural model and run the different analysis that can be required during the design of the rotor of a OWT
- To be capable of defining the material that suits best for any situation
- To know the similarities and differences of OWT devices with that harness energy from sea waves and currents.
- To know the possibilities of using the hydrogen as energy vector, for storage or transport

Title: **MANUFACTURING AND MARINE OPERATIONS** **7 credits**

Ref : EMSHIP+_M2-UPM-4
**Prof : J. DOMÍNGUEZ** **Teaching Period: sem. 3**

Link :
http://www.etsin.upm.es/English/Estudios/Postgrado/Master%E2%80%99s%20Degree%20on%20Marine%20Renewable%20Energies%20Harnessing
and
https://moodle.upm.es/titulaciones/propias/course/view.php?id=1452

**1) Objectives**

- Understanding the offshore fabrication techniques, relevance of interfaces and all activities for sail away.
- Knowledge of marine vessels and ability to select the most appropriate offshore vessels set. Ability to define the most suitable transport and installation strategies.
- Understanding the figures involved in granting permits for marine operations and decision-making procedures under HES criteria.
- Understanding of the construction phases happening offshore

**2) Contents**

Fabrication

- Manufacturing strategies
- Load-Out

Marine vessel deployment

- Vessel typologies spectrum
- Transport and installation operational requirements

Marine operations

- Marine warranty surveyor
- Harbour logistics
- Transport operations
- Installation operations
- Complementary installation strategies
- Submarine cable laying
- Commissioning
- Offshore logistics
- Health & safety
- Environment

Operation and Maintenance

- Maintenance
- Marine logistics for O&M
- Assets operation. Operational tools

Exam course : (2 hours)

**3) Academic staff**

Jaime Domínguez Soto, Course coordinator
Pablo Gómez Alonso / Vicente Negro Valdecantos / José Santos López Gutiérrez / Dolores Esteban Pérez / Enrique de Faragó Botella / Jose Manuel García Muniña / Jonay Cruz Fernández / Manuel Aguinaga Arena / Juan Luis Paredes

**4) Bibliography**


- Construction of Marine and Offshore Structures - Ben C. Gerwick
- API Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – API RP 2A
- DNVGL-OS-C401 Fabrication and Testing of Offshore Structures
- DNVGL-ST-N001 Marine operations and marine warranty
- DNVGL RP-J301 Subsea Power Cables in Shallow Water Renewable Energy Applications


**Learning outcomes of the course**

- Understanding the load-out operation from the impact on design and fabrication to the load-out sequence and the benefits of feedback engineering-fabrication
- Understanding of the operation requirements for marine operations to define the vessels for best selection for each marine operation and for the future for the renewable business
- Understanding the certification process that rules the marine operation authorization
- Understanding the characteristics of the marine transportation to select the most suitable transport means and port selection
- Understanding the different phases involved in the installation process and new challenges ahead accounting for deeper and heavier structures
- Knowledge on the characteristics of the logistics required to support the offshore commissioning activities and personnel offshore
- Understanding of the paramount importance of the H&S concept, specific training and countries regulations to reduce risks during execution and operation of the platforms
- Understanding of the environmental impact and mitigation measures of the installation and maintenance works
- Understanding of the different maintenance strategies and the resources to be mobilized in the different maintenance typologies. Risk attenuation, insurances
- Understanding of the mutual influence between the ship design and the selected maintenance strategy

Title: **PROJECT OPERATION AND MANAGEMENT** **4 credits**

Ref : EMSHIP+_M2-UPM-5
**Prof : S. FERNÁNDEZ** **Teaching**
**Period: sem. 3**

Link :
http://www.etsin.upm.es/English/Estudios/Postgrado/Master%E2%80%99s%20Degree%20on%20Marine%20Renewable%20Energies%20Harnessing
and
https://moodle.upm.es/titulaciones/propias/course/view.php?id=1453

**1) Objectives**

- Sound knowledge of the political, economic and technological drivers guiding the development of the MRE (Marine Renewable Energy)
- Full comprehension of the different phases of a MRE Project and the specific characteristics of each one of them: Development, Permits, Construction and Operation and its financial inputs and outputs
- Knowledge of the different approaches to develop, build and operate a MRE project. Cost structure of the project and differences among the different possibilities.
- Sound knowledge of the building up of a MRE Project business case and the different possibilities for its financing.
- Robust knowledge of the different approaches to monetize risks. Contingency concept and valuation.
- Understanding of the main risks arising during the different development phases of a RME Project. Classification, evaluation and mitigation of these risks. Contingency management.

**2) Contents**

Financial Principles

- Development phases of a Power Production Project. Specific case of an OWF. Development, Permits, Construction and O&M. FID Milestone.
- Environmental & socio-economic impact of the MRE
- Economic remuneration to the marine energy projects. Regulation in Germany, UK and France. Status in Spain.
- Cost structure of a Renewable Marine Energy Project. Turn Key Projects vs. Package Split. Packages splitting levels and needs for owner's resources.
- Valuation of an Energy Project. IRR/VNA/WACC. The business plan.
- Project financing modalities. Non-recourse financing: "Project Finance".
- Principles of risk assessment. Concept of contingency.

Exam course: (2 hours)

**3) Academic staff**

Salvador Fernández Uranga, Course coordinator
Jose Ignacio González Iglesias / Laura Rol Rúa / Miguel Sánchez Calero / Jose Luis Morán / Ricardo Izquierdo Labella

**4) Bibliography**

- FIDIC. A guide for practitioners. Axel-Volkmar Jaeger & Dr. Götz-Sebastian Hök. Springer-Verlag Berlin Heidelberg 2010
- Financing Large Projects: Using Project Finance Techniques and Practices M. Fouzul Kabir Khan & Robert J. Parra. Prentice Hall College Div 2007 Random

- East Anglia ONE Offshore Windfarm. 500MW – 600MW Project. Supply Chain Plan. Available in www.gov.uk
- Estimating Project Cost Contingency-A model and exploration of research questions. David Baccarini-2004
- A decision support tool for the Risk Management of offshore Wind Energy Projects-2013
- Project Definition Rating Index PDRI RR113-11 CII-1996
- Project Risk Analysis and Management. The association for Project Management
- A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – Fifth Edition
- Specification for Invitation to Tender No. 2011/S 126-208873 relating to offshore power generation wind installations in Metropolitan France. Available in French in www.cre.es
- BIMCO Time Charter Party for Offshore Service Vessels. Baltic and International Maritime Council
- A review of regulatory framework for wind energy in European Union countries: Current state and expected development. Javier Serrano González, Roberto Lacal-Arántegui
- European Commission, Joint Research Centre, Institute for Energy and Transport, Westerduinweg 3, NL-1755 LE Petten, The Netherlands. Available in http://ac.els-cdn.com/S1364032115013581/1-s2.0-S1364032115013581-main.pdf?_tid=51057716-67e9-11e7-ba13-00000aacb360&acdnat=1499963924_83fecf7eb89141221c9143ba5231d533
- Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources. Available in: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016PC0767R%2801%29

**Learning outcomes of the course**

- Comprehension by the students of the phases of an ERM Project, with specific understanding of the main drivers in each stage.
- The student will acquire knowledge about the possible interactions with the environment and society during the processes of development, construction and operation of the plant and the measures taken to manage them.
- The student will have a wide comprehension of the different regulatory models applied to the RME in the European countries where these energies are being developed. Restrictions caused by the need of local content in the Supply Chain.
- The student will acquire knowledge about the costs in a RME Project. Both direct costs as the acquisition of the supplies and services needed for the construction and operation of the facility, as the indirect costs with a commercial or financial character, as insurances or financing.
- The student will acquire a sound knowledge of the concepts used in projects valuation and the final investment decision. Energy indicators and concept of business case, application to an OWF project.
- The way in which a project is financed has influence in all areas of the project, managerial, technical and economical. Therefore, the student has to have knowledge of the different possibilities to finance a project, especially the possibility to finance it without recourse to the shareholders. Differences with rest of possible financing models, effects on the final costs and financial results. Banking conditioning

Title: **STRUCTURAL ANALYSIS OF OFFSHORE PLATFORMS** **4 credits**

Ref : EMSHIP+_M2-UPM-6
**Prof : M.A. HEREROS** **Teaching Period: sem. 3**

Link :
http://www.etsin.upm.es/English/Estudios/Postgrado/Master%E2%80%99s%20Degree%20on%20Marine%20Renewable%20Energies%20Harnessing
and https://moodle.upm.es/titulaciones/propias/course/view.php?id=1454

**1) Objectives**

- Preparation of a Finite Element model of a foundation and integration with tower & WTG models
- Preparing the analysis: site description, load case definition and creating the load environment in the FEM.
- Running the FEM analysis and assessment of results
- Sizing the model for the test on a basin.
- Selection of the load conditions and site constraints
- Being able to perform results comparison between numerical models and experiments

**2) Contents**

Full-Structural Design of a substructure for a WTG

- Case study: jacket, monopile, by modelling with ANSYS.
- Building the model and applying constraints
- Definition of a specific site and building the design load cases
- Sequential analysis: tower & WTG with foundation

Testing an offshore foundation on basin

- Definition of model for test basin
- Preparing the model for testing and load conditions
- Test result comparison test basin vs. Software modelling

**3) Academic staff**

Miguel Ángel Herreros, Course coordinator
Mario de Vicente / Luis Pérez Rojas

**4) Bibliography**


- E. Oñate: Cálculo de estructuras por el método de los elementos finitos. 1-análisis estático lineal, 2- análisis no lineal, CIMNE, 1992.
- Zienkiewicz O. O.: The finite element method, mcgraw-hill, 1989.
- Bathe, K. J.: Finite element procedures. 2nd ed. klaus-jürgen bathe, 2014.
- Offshore Structures: Design, Construction and Maintenance By Mohamed El-Reedy. Gulf Pub. Co., Book Division. ISBN: 978-0-12-385475-9
- Introduction to offshore structures: design, fabrication, installation. William J. Graff. Gulf Pub. Co., Book Division.
- Essentials of Offshore Structures: Framed and Gravity Platforms. D.V. Reddy, A. S. J. Swamidas. CRC Press.
- Offshore Wind Power. Edited by John Twidell and Gaetano Gaudiosi. Multi-Science.
- WEB resources. “Ocean Wave Interaction with Ships and Offshore Energy Systems” http://ocw.mit.edu/courses/mechanical-engineering/2-24-ocean-wave-interaction-with-ships-and-offshore-energy-systems-13-022-spring-2002/ at MIT-OPEN-COURSE-WARE®
- NREL – National Renewable energy Laboratory. NREL Publications Database /http://www.nrel.gov/publications/

| |
|---|
| - Chopra A.: Dynamics of structures. Theory and applications. Edited by Prentice Hall, 2000 ISBN: 0130869732 |
| **Learning outcomes of the course**<br>- Ability to perform a numerical model analysis and sizing a WTG structure<br>- Ability to assess the equivalent model for test basin<br>- Ability to build the equivalent design load cases for test basin<br>- Understanding of differences between numerical modelling and testing on a basin, and obtaining conclusions |