Syllabus Cursus Master's Degree in Engineering, Mechanics.

Sorbonne University CMI5

Computational Mechanics (Comp Mech)

List of Teaching Units

Semester 9

- Technoscience, ethic and society
- Fracture mechanics
- Non-linear behaviour of solids
- Damage
- Numerical calculation of non-linear structures
- Introduction to hydrodynamical instabilities
- Turbulence: dynamics and modelling
- Numerical methods for fluid mechanics
- Quantification of uncertainty
- Project in non-linear calculation

Semester 10

- Certification
- Deepening Project
- Graduation internship

Title Teaching Unit - Master Cycle – CMI5		Code	Lecture	Discussion sessions	Lab	SSA	Hours Attendance	Work Personal	ECTS
CMI5 S9	Technoscience, ethic and society	MU5EEG03	16	8		24	24	40-60	6 *
	Fracture mechanics	MU5MES02	30				30	30	3
	Non-linear behaviour of solids	MU5MES03	30				30	30	3
	Damage	MU5MES05	30				30	30	3
	Numerical calculation of non-linear structures	MU5MES01	30				30	30	3
	Introduction to hydrodynamical instabilities	MU5MEF19	28	2			30	20-30	3
	Turbulence: dynamics and modelling	MU5MEF22	30	22	8		30	50-60	6
	Numerical methods for fluid mechanics	MU5MEF19	15	15			30	20-30	3
	Quantification of uncertainty	MU5MEF39	14	14	6		30	20-30	3
	Project in non-linear calculation	MU5MEF32	4				4	80	3

Title Teaching Unit - Master Cycle – CMI5		Code	Lecture	Discussion sessions	Lab	SSA	Hours Attendance	Work Personal	ECTS
CMI5 S10	TOIC /TOEFL certification	MU4LVANT				30		30-40	3*
	Deepening Project	MU5EEG04				40		50-60	3*
	Graduation internship	MU5MES03					800	80-100	30
Total CMI5 - S10 30 ECTS + 6 *									

*Units outside the contract (not included in the calculation of the semester average (appear in the Diploma Supplement)

Semester 9

Technosciences, Ethic and Society

Level CMI5 - **Semester** S9 - **Credits** 6 ECTS - **Code** MU5EEG03 - Master's **mention**

Pedagogical presentation.
The objective of this course is to bring students to reflect on the social and ethical dimensions of the engineering profession. It focuses on the complex relations between society and technology, and in particular on the role of technology as a value carrier. Based on these analyses, the course then explores the ethical questions and dilemmas that engineers may encounter in the course of their work. Particular attention is paid to examining classic cases in engineering ethics, such as Three Mile Island and the Quebec Bridge. By the end of this course, students will be able to identify ethical issues raised by professional practices. They will also be reflective on their future profession. The course is taught in English.

Content of the Teaching Unit.

- Introduction
- Technical determinism and social construction. Read: T. Pinch and W. Bijker, The Social Construction of Facts and Artifacts? Presentation: (also) Robert Heilbroner, Do Machines Make History?
- Devices, systems, and their power of action on society. Read: B. Latour, Where are the Missing Masses? The Sociology of a Few Mundane Artifacts. Presentation: (also) T. Hughes, Technological Momentum.
- Techniques et valeurs. Lire : J. Wetmore, A. Technology : Reinforcing Values, Building Community. Exposé : (aussi) LangdonWinner, Do Artifacts Have Politics ? et R. Weber, Manufacturing Gender in Commercial and Military Cockpit Design.
- Complexity and uncertainty. Bring: Proposal for a dissertation Read: D. Vinck, Engineers in everyday life. Lecture : (also) JamesonWetmore, Engineering Uncertainty.
- Engineering and experimentation. Read, lecture: M. Martin and R. Schinzinger, Introduction to Engineering Ethics, pp. 77-103.
- Technical disasters. Reading and presentation: S.K.A. Pfaitteicher, Lessons amid the Rubble, pp. 36-61.
- Engineering and security. Reading and presentation: Mike Martin and Roland Schinzinger, Ethics in Engineering, pp. 117-145.
- Engineering and environment. Reading, presentation: Mike Martin and Roland Schinzinger, Ethics in Engineering, pp. 219-242.
- Nanotechnologies, génétique et robotique. Lire: Bill Joy, Why the Future Doesn't Need Us. Exposé : Interagency Working Group on Nanoscience, Engineering, and Technology, Nanotechnology : Shaping theWorld Atom by Atom.

Prerequisite. The corpus of societal and cultural opening lessons of the LECTUREI course followed since the 1st year.

References. Bowen R. 2012. Engineering Innovation in Health Care : Technology, Ethics and Persons. HRGE, pp. 204-221. Collins, Harry & Trevor Pinch. 2002. The Golem at Large : What You Should Know about Technology. Cambridge University Press. Didier. Ch. 2008. Penser l'éthique des ingénieurs. Paris, PUF. Didier, C.. 2008. Les ingénieurs et l'éthique : pour un regard sociologique. Hermes Science publications. Heilbroner, Robert. 1967. Do Machines Make History? Technology and Culture, pp. 335-345. Hughes, T. 1994. Technological Momentum, in Marx, Leo & Merritt Roe Smith, Does Technology Drive History? The Dilemma of Technological Determinism. Cambridge: MIT Press, pp. 101-113. Interagency Working Group on Nanoscience, Engineering, and Technology, Nanotechnology: Shaping the World Atom by Atom, in Johnson, Deborah et Jameson Wetmore. Technology and Society: Building Our Sociotechnical Future. MIT Press Johnson, D. & Jameson W.. 2008. STS and Ethics: Implications for Engineering Ethics, in Hackett, Edward, Olga Amsterdamska, M. Lynch et J. WajLecturean, The Handbook of Science and Technology Studies. Cambridge, MIT Press, pp. 567-582. Joy, Bill. Avril 2000. Why the Future Doesn't Need Us,Wired, pp. 238-262. Latour, B. 1992. Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts in Wiebe Bijker et John Law, Shaping Technology/Building Society: Studies in Socio-technical Change. Cambridge, MIT Press, pp. 225-258. Martin, Mike & Roland Schinzinger. 2005. Ethics in Engineering. McGraw-Hill. Martin, M. & Roland S.. 2010. Introduction to Engineering Ethics. New York : McGraw- Hill. Pfattaicher, S. K. A. 2010. Lessons Amid the Rubble. Johns Hopkins University Press. Pinch, Trevor & Wiebe Bijker. 1987. The Social Construction of Facts and Artifacts in Wiebe Bijker, Thomas H.,Trevor P., The Social Construction of Technological Systems. Cambridge, MIT Press, pp. 17-50. Vinck, D. 1999. Ingénieurs au quotidien : ethnographie de l'activité de conception et d'innovation. Presses universitaires de Grenoble. Weber R.. 1997.

Manufacturing Gender in Commercial and Military Cockpit Design, Science, Technology, & Human Values, pp. 235-253. Jameson. 2008. Engineering with Uncertainty: Monitoring Air Bag Performance, Science and Engineering Ethics, pp. 201-218. Jameson. 2009. Amish Technology: Reinforcing Values, Building Community in Johnson, D. et Jameson W.. Technology and Society: Building Our Sociotechnical Future. Cambridge: MIT Press. -Winner, Langdon. 1986. Do Artifacts Have Politics? The Whale and the Reactor: a Search for Limits in an Age of High Technology. University of Chicago Press, pp. 19-39.

Resources available to students. Lecture materials. List of books.

Scientific knowledge developed in the unit.

- Knowledge of the social and ethical dimensions of the engineering profession.

Skills developed in the unit.

- Improvement of the knowledge of English. Improvement of written expression.
- Forms of reasoning practiced in the social sciences.

Hourly volumes in and out of the classroom.

Total attendance hours: 24 hours divided into 16 hours of class, 8 hours of discussion sessions. Personal work 40-60 hours.

Evaluation. Attendance at sessions: 20%, Presentation: 20%, Essay: 40%, Essay defence: 20%.

Teacher. C. Lecuyer

SCIENCES SORBONNE UNIVERSITÉ

Mechanics of brittle fracture

Level CMI5 - **Semester** S3 - **Credits** 3 ECTS - **Code** - Master's degree in Mechanics / Solid Mechanics. Materials and structures.

Pedagogical presentation.
This course aims at exposing the basics of the brittle fracture theory, as it is commonly used in research laboratories and advanced industry (nuclear, aeronautics, ...) to predict and control the cracking of materials. The materials considered are mainly metallic materials for which the students have a good culture (behaviour at the scale of the crystal structure) either via the CMI4 or CMI5 level courses.

Content of the Teaching Unit.
The course includes 2 chapters on basic knowledge and a third one a little more specialized.

- Irwin's theory of KIc.
- Griffith's energy theory.
- Crack propagation in mixed mode.

Prerequisite. Solid Mechanics Master 1 level.
Good bases of practical mathematics (elementary algebra and analysis, differential equations, fonctions of a complex variable, calculations).

Bibliographical references.

- Leblond J. B. , Mechanics of ductile and brittle fracture, Hermes, 2003.
- Griffith A.A., The phenomena of rupture and flow in solide, Philosophical Transactions of the Royal Society of London, série A, vol. 221, 1921, p. 163–198
- E. Erdogan (2000) Fracture Mechanics, International Journal of Solids and Structures, 27, p. 171–183.

Resources available to students.
Course notes and annals.

Scientific knowledge developed in the unit.

- At the end of the EU, the student has the basic tools of brittle fracture mechanics, set out in an exhaustive and detailed manner, enabling him or her either to meet the requirements of a mechanical engineering office or to undertake a thesis in the field.

Skills developed in the unit.

- Calculation of crack propagation in simple cases.

Hourly volumes in and out of the classroom.
Total Attendance Hours: 30 hrs (integrated lecture and discussion sessions): Personal Work 30 hrs.

Evaluation.
The evaluation is based on a written report lasting 3 hours.

Teacher. Mr J.B. Leblond

Non-linear behaviour of solids

Level CMI5 - **Semester** S3 - **Credits** 3 ECTS - **Code** - Master's degree in Mechanics / Solid Mechanics. Materials and structures.

Pedagogical presentation.
Assessment of non-linear behavioural laws in a classical thermodynamic context.

Content of the Teaching Unit.
- Brief reminder of the basic concepts of continuous media mechanics and the various behaviours of structural materials
- Thermomechanical balance laws for continuous media: momentum balance, energy balance and entropy balance. Presentation of Clausius-Duhem inequality and dissipation (intrinsic and thermal)
- Generalized standard materials framework: general method of formulating behavioural laws; role of Clausius-Duhem inequality. Notions of state variables, internal variables, state functions and thermodynamic potentials. Equation of heat. Construction and identification of the main classes of behavioural models: recalls of the fundamental rheological models based on spring, shoe and damper. Case of thermoplastic materials, thermo-viscoelastic materials (Kelvin-Voigt model, Maxwell model)
- Elasto-plasticity and applications: Formulation of perfect elasto-plastic models. Consideration of strain hardening (isotropic and/or kinematic). Thermo-mechanical calculations and simple problem solving of elasto-plastic structures.
- Some notions on laws coupling elasticity and isotropic damage
- Elasto-visco-plastic behaviour. Presentation of some models of time-dependent behaviour; viscosity regulating effect.

Prerequisite. Solid Mechanics Master 1 level.

Bibliographical references.

- H. Ziegler, An introduction to thermoechanics, North Holland, 1983
- P. Germain, Q. S. Nguyen, P. Squat, Continuum Thermodynamics, J. Appl. Mech., ASME 50, 1010-1021, 1983.
- J. Lemaître, J. L. Chaboche, Mechanics of Solids Materials, Cambridge University Press, 1990
- G. Maugin, The thermomechanics of plasticity and fracture, Cambridge University Press 1992
- Q. S. Nguyen, Stability and Nonlinear Solids Mechanics, Wiley, 2000
- M. Fremond, Non Smooth Thermomechanics, Springer Verlag, 2002,
- J. Lubliner, Plasticity Theory. Dover Publications Inc., Mineola, New York, 2008.
- H. Maitournam, Matériaux et Structures inélastiques, Éditions de l'École Polytechnique, 2016

Resources available to students. Annals.

Scientific knowledge developed in the unit.
- Master the modelling of non-linear material behaviours.

Skills developed in the unit.
- Choice of a model for a given use.
- Identification of a complex behavioural law from experimental data provided.

Hourly volumes in and out of the classroom.
Total Attendance Hours: 30 hrs (integrated lecture and discussion sessions): Personal Work 30 hrs.

Evaluation.
The evaluation is based on a written report lasting 3 hours.

Teacher. Mr D. Kondo

Damage

Level CMI5 - **Semester** S9 - **Credits** 3 ECTS - **Code** MU5MES05 - Master's degree in Mechanics / Solid Mechanics. Materials and structures.

Pedagogical presentation.
The objectives of this teaching are:

- to provide the theoretical basis for the damage mechanics of quasi-fragile materials, in particular concerning the formulation of macroscopic behavioural laws coupling elasticity and damage.
- to study the problem of the initiation and evolution of damage in a numerical framework in order to address the poorly-positioned nature of local damage models and then to propose an opening towards several regularization techniques and links to brittle fracture models.

Content of the Teaching Unit.
After a brief introduction on the microscopic origin of damage as a process that changes the macroscopic properties of materials, the sessions of this course will be dedicated to :

- the formulation of the law of elastic-damageable behaviour in the context of irreversible thermodynamic processes (generalized standard materials) ;
- the introduction of the notion of damage criterion (threshold surface), of associated thermodynamic force (energy restitution rate) and of damage evolution law ;
- the simple implementation of an isotropic damage model in a finite element calculation code (FEniCS) ;
- the study of the malpositioning of local damage models (mesh dependence) and a presentation of different regulation techniques (non-local models) ;
- numerical implementation of `gradient damage models (phase-field) for the simulation of crack propagation in brittle materials;

Prerequisite. Mechanics of continuous media. Thermodynamics, numerical calculation (finite element method).

Bibliographical references.

- Lemaitre, J., Chaboche, J. L., Benallal, A., & Desmorat, R. (2009). Mechanics of solid materials - 3rd edition. Dunod.
- Pijaudier-Cabot G., Mazars J. (2001). Damage models for concrete. in Handbook of Materials Behavior. Vol. II, Lemaitre J. (ed.), Academic Press
- Marigo,J.J., Maurini, C.,& Pham, K.(2016). An overview of the modelling of fracture by gradient damage models. Meccanica, 51(12), 3107-3128.

Resources available to students. Course materials, Annals.

Scientific knowledge developed in the unit.

- Damage Modelling.
- Calculation of damaged structures.
- Crack propagation.

Skills developed in the unit.

- Implementation of a damage law in a calculation code.
- Respect of procedures during code development.

Hourly volumes in and out of the classroom.
Total Attendance Hours: 30 hrs (integrated lectures and discussion sessions): Personal Work 30 hrs.

Evaluation.
The evaluation is based on a written report lasting 3 hours.

Teacher. Mr D. Kondo & Mr J. Bleyer

Numerical calculation of solids and non-linear structures

Level CMI5 - **Semester** S3 - **Credits** 3 ECTS - **Code** - Master's degree in Mechanics / Solid Mechanics. Materials and structures.

Pedagogical presentation.
The aim of the teaching is to solve nonlinear solid mechanics problems on computer by implementing the finite element method and solving algorithms. Students will be introduced to the use of modern high-performance scientific computing tools (FEniCS, PETSc), visualization tools (paraview) and project management (git).
Content of the Teaching Unit.

- Linear elasticity, variational formulation, discretisation: Reminder on how to solve a finite element mechanics problem. Getting to grips with python and FEniCS, Solving an elasticity problem using FEniCS.
- Non-linear elasticity: Non-linear elasticity, linearization, buckling, stability. Solving a problem of non-linear elasticity, buckling and post-buckling.
- Non-linear dynamics: Implicit, explicit methods. Solving problems of nonlinear dynamics.
- Project: working on a project in pairs.

Prerequisite. Mechanics of environments continus - Knowledge of a programming language (ideally python), - Basic course on finite elements and numerical methods

Bibliographical references.

- Belytschko T., Liu W. K. and Moran B., Non linear finite elements for continua and structures, 2000, Wiley.
- Dhatt G., Touzot G. and Lefrancois E., Une présentation de la méthode des éléments finis, 2005, Hermes.
- Holzapfel G.A., Nonlinear solid mechanics, 2000, Wiley.
- Scott R., Introduction to Automated Modelling with Fenics, 2018, Computational Modelling Initiative LLC.
- Langtange, P. and Logg A., Solving PDEs in Python, 2017, Springer.
- Davide Bigoni Nonlinear Solid Mechanics Bifurcation Theory and Material Instability, 2012, Cambridge University Press.
- Wriggers, P., Nonlinear finite element method, 2008, Springer.
- Bonnet M., Frangi A., Rey C., The finite element method in solid mechanics, 2014, McGraw Hill.

Resources available to students. Annals.

Scientific knowledge developed in the unit.

- Ability to develop numerical code based on the finite element method to solve a linear and nonlinear elasticity problem in static or dynamic using the python language and the FEniCS library
- Non-linear elasticity, explicit and implicit methods for structural dynamics, numerical study of bifurcation and stability in the quasi-static framework.
- Introduction to revision management systems (git), Introduction to visualization and meshing tools, Use of large linear and nonlinear equation system solvers

Skills developed in the unit.

- Group work within the proposed project.
- Report and presentation.

Hourly volumes in and out of the classroom.
Total Attendance Hours: 30 hrs (integrated lectures and discussion sessions): Personal Work 30 hrs.

Evaluation.
The evaluation is based on a written report lasting 3 hours and a report associated with a mini-defence.

Teacher. Mr D. Duhamel, Mr C. Maurini

Hydrodynamic instabilities

Level CMI5 - **Semester** S9 - **Credits** 3 ECTS - **Code** MU5MEF15 Master of Mechanics - Fluid Mechanics and Applications.

Pedagogical presentation.
Master the analytical tools to solve problems, mainly in fluid mechanics, in which very different scales are present. To provide advanced knowledge in incompressible fluid mechanics, through the study of analytical solutions and classical asymmetry.

Content of the Teaching Unit.
The method of asymptotic paired developments is introduced, in which the ratio of scales appears as a small parameter in the equations. Examples: simple ordinary differential equations, and fluid flows with boundary layers. Low Reynolds numbers, Stokes equations, dissipation theorems, falling-body dynamics, Oseen approximation. High Reynolds numbers: special solutions, self-similar jet and wake solutions.

Prerequisites. Basics of fluid mechanics.

Bibliographical references.

- Radyadour K Zeytounian, Asymptotic Modelling in Newtonian Fluid Mechanics, Berlin; Heidelberg; Paris: Springer-Verlag, cop. 1994.

Resources available to students. Handout and course materials.

Scientific knowledge developed in the unit.

- Asymmetrical development method.

Skills developed in the unit.

- Master the analytical tools to solve problems.
- Application to simple cases of asymptotic developments.

Hourly volumes in and out of the classroom.
Total attendance hours: 30 hours (Lecture and discussion sessions). Expected personal work: 20 - 30 hrs.

Evaluation. Final written exam.

Teacher. S. Zaleski & P.Y. Lagrée

Turbulence dynamics and modelling

Level CMI5 - **Semester** S9 - **Credits** 6 ECTS - **Code** MU5MEF22 Master of Mechanics - Fluid Mechanics and Applications.

Pedagogical presentation.
The objective of this course is to provide the basics of the physical theory of turbulence and its statistical modelling for numerical simulation. A presentation of the different basic concepts and theoretical tools will be given.

Content of the Teaching Unit.
The course is structured as follows:

- Introduction & definition of turbulent flow
- Basic concepts and tools (introduction to statistical description and modelling)
- Isotropic Turbulence: Dynamics and Modelling
- Homogeneous anisotropic turbulence: definition in the sense of Craya, theory of rapid distortion, case of pure cisaillement cisaillement
- Turbulence boundary layer: qualitative effects of the presence of a solid wall, averaged equations, analyse physics of measurement and simulation results, analytical solution for the mean field, dynamics of coherent structures, notion of very large scales of motion and deviation from theory, notion of autonomous dynamic cycle and regeneration of turbulence

Prerequisites. Basic knowledge of fluid mechanics

Bibliographical references.

- Pope, S.B., Turbulent flows, Cambridge University Press, 2000
- Tennekes-Lumley A first introduction to turbulence The MIT press 1972

Resources available to students. Course notes

Scientific knowledge developed in the unit.

- Modelling turbulent flows (isotropic or not).
- Boundary layer in turbulence.

Skills developed in the unit.

- Manipulate the different equations of turbulence.

Hourly volumes in and out of the classroom.
Total attendance hours: 60 hours divided into 30 hours of lecture, 22 hours of discussion sessions and 8 hours of Lab. Expected personal work: 40 - 50 hrs.

Evaluation. Examinations: Exam 1 (50%) and Exam 2 (50%).

Teacher. S. Chibbaro

Numerical methods for fluid mechanics

Level CMI5 - **Semester** S9 - **Credits** 3 ECTS - **Code** MU5MEF16 Master of Mechanics - Fluid Mechanics and Applications.

Pedagogical presentation.
The objective of the course is to bring the audience to a high level of understanding of numerical fluid dynamics with unstructured meshes adjusted to the body. The course will focus mainly on finite volume and finite element methods for Navier-Stokes equations, incompressible and compressible with or without turbulence models. Mesh generation will also be discussed. The content of well-known software such as Fluent will also be analysed. Illustrations and numerical exercises will be made with our internal open source software freefem++.

Content of the Teaching Unit.
Stokes' equations and difficulties explained on a uniform grid of finite differences. Variational formulations for the incompressible Navier-Stokes equations. Mesh generation and adaptation. A finite element approximation solver for convection-diffusion and pressure projection. A finite volume method for compressible Navier-Stokes equations. Difficulties and solutions for the k-epsilon turbulence model; wall laws and weak shape of boundary conditions.

Prerequisite. Basic knowledge of EDP, knowledge of a popular programming language.

Bibliographical references.
- https://freefem.org/

Resources available to students. Handout and course materials.

Scientific knowledge developed in the unit.
- Variational approach to the Stokes equations
- Finite volumes and finite differences.
- Weak form of boundary conditions.

Skills developed in the unit.
- Programming on FreeFem++ of the Navier Stokes equations in the studied case.
- Write the different equations and boundary conditions.

Hourly volumes in and out of the classroom.
Total attendance hours: 30 hours (lectures and discussion sessions). Expected personal work: 20 - 30 hrs.

Evaluation. Final written exam.

Teacher. F. Hecht & O. Pironneau

Quantification of uncertainties in CFD

Level CMI4 - **Semester** S9 - **Credits** 3 ECTS - **Code** MU5MEF39 Master of Mechanics - Fluid Mechanics and Applications.

Pedagogical presentation.
The objective of this course is to become familiar with the concepts/tools of uncertainty quantification and stochastic/statistical Modelling of engineering problems, particularly in the context of Computational Fluid Mechanics (CFD). Different stochastic methods based on probability theory will be discussed to enrich the classical deterministic numerical prediction of the mechanical system. These techniques allow in particular a better control of the numerical error, obtaining
This includes the identification of "error bars", the identification of influential parameters such as the study of the sensitivity of the system, the propagation of uncertainties, and risk analysis.
The stochastic models and numerical methods presented will be implemented for concrete examples of fluid flows during computer-based PT with the Matlab software.

Content of the Teaching Unit.
The course is organized as follows:

- Introduction to uncertainty quantification in numerical mechanics
- Probability/statistic reminders
- Introduction to Stochastic Simulation Methods
- Formalism and derivation of stochastic spectral representations
- Digital resolution methods
- Robust optimization
- Applications: illustration on concrete examples of fluid flows revisited in an uncertain context.

Prerequisites. Mastery of basic notions in probability and statistics facilitates the understanding and acquisition of the concepts of this TU.

Bibliographical references.

- Stochastic finite elements, Ghanem & Spanos, Dover 2003
- Numerical methods for stochastic computations : a spectral methods approach, Xiu, Princeton University 2010
- Stochastic Simulation: Algorithms and Analysis, Asmussen & Glynn, Springer 2007

Resources available to students. Course notes

Scientific knowledge developed in the unit.

- Modelling uncertainties and their propagation.

Skills developed in the unit.

- Identify influential parameters.
- Implant and a stochastic model in Matlab.
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Hourly volumes in and out of the classroom.
Total attendance hours: 34 hours divided into 14 hours of lecture, 14 hours of discussion sessions and 6 hours of Lab. Expected personal work: 20 - 30 hrs.

Evaluation. Report from LAB Matlab (20% + 30%) + 1 final written exam (50%)

Teacher. Arnaud Antkowiak

Digital Project

Level CMI5 - **Semester** S9 - **Credits** 3 ECTS - **Code** MU5MEF32 Master of Mechanics - Fluid Mechanics and Applications.

Pedagogical presentation.
This project aims to put into practice all the concepts seen in the course of the project on the basis of a case study. The students will mainly have to confront analytical methods with numerical solutions after a bibliographical study which will allow them to make a reasoned choice of the methods to be used.

Content of the Teaching Unit.
The content is associated with the topic that covers (more or less) the entire programme.

Prerequisites. Master's courses.

Bibliographical references. Depends on the subject and must be researched by the students.

Resources available to students. Software records, bibliographical research tools.

Scientific knowledge developed in the unit.

- Complementary training specific to the subject worked on.

Skills developed in the unit.

- Apply the concepts seen in class to practical cases.
- Choose the appropriate numerical methods.
- Programming, using calculation codes.
- Write and present an internship report.

Hourly volumes in and out of the classroom.
Total attendance hours: 4 hours of project presentation. Expected personal work: 60 - 80 h.

Evaluation. Written project report (50%), oral presentation (50%).

Teacher. A. Antowiak

Semester 10

Deepening Project

Level CMI5 - **Semester** S10 - **Credits** 3 ECTS - **Code** MU5EEG04 - Master's **degree in** Mechanics

Pedagogical presentation.
This deepening project is complementary to the specialization and can take different forms. It can represent the follow-up of an optional unit of additional specialization in semester S9 to broaden the knowledge base or to enhance a bibliographical part of the internship that would have been significant, or be associated with a scientific production for example in the context of the internship (presentation in a scientific conference, submission of a publication). It can also valorise an important associative investment or translate the validation of a teaching in the form of a MOOC (for example, a shared teaching on the European Virtual Exchange platform of the Sorbonne University Alliance 4eu+ network of partner universities: Charles University of Prague (Czech Republic), Heidelberg (Germany) and Warsaw (Poland), Universities of Milan (Italy) and Copenhagen (Denmark)). This project is usually carried out on an individual basis.

Content of the Teaching Unit.
Depending on the form of the project

Prerequisite miminum. Knowledge acquired in all teaching units since CMI1.

Bibliographical references. Function of the project subject.

Resources available to students. Function of the project subject and its environment.

Scientific knowledge developed in the unit

- Function of the project subject.

Skills developed in the unit.

- Take a step back from his training path.
- Knowing how to manage a personal project with commitment, defending it with conviction.

Hourly volumes in and out of the classroom.
Expected personal work: about 30 - 40 hours (and often more).

Evaluation. Evaluation usually in the form of a note of the written report, oral defence and involvement.

Teacher. Y. Berthaud, H. Dumontet.

SCIENCES SORBONNE UNIVERSITÉ

Graduation internship

Level CMI5 - **Semester** S10 - **Credits** 30 ECTS - **Code** MU5MES03 - **Mention** Master Mechanics

Pedagogical presentation.
This end-of-study internship takes place over 24 weeks at the end of the course. The objective is to enable the student to acquire an engineering attitude, in particular autonomy and the ability to work effectively in a team in the company, by relying on the knowledge acquired during the training and the skills developed in the simulation activities (projects, and previous internships). He consolidates the specialization and validates these acquired skills.

This internship can take place in France or abroad, in a company (generally in the R&D departments of large industrial groups) or research laboratory (provided that the student then has significant experience of an internship in a company). It leads to the writing of a report and a defence in French or English. The presentation is made in front of a mixed jury composed of members of the teaching team and external experts, including the supervisor in the case of an internship in a company.

Content of the Teaching Unit.
The course leaders validate the coherence of the subject, its adequacy with the speciality of the training, with the student's professional project and his/her academic results. This internship is the subject of an internship agreement signed by the company/laboratory, the university and the student.

Prerequisite miminum. All the knowledge and skills developed since the beginning of the course.

Resources available to students.

- List and description of previous internship topics. Internship offers.
- Validation procedures, drafting guidelines, internship agreements.
- Bibliographical resources according to the subject.

Scientific knowledge developed in the unit.

- Specific to each internship according to the subject area of the company / laboratory and the missions entrusted.

Skills developed in the unit.

- Knowing how to participate in teamwork, take initiatives, know how to situate oneself and acquire autonomy.
- Know how to apply one's knowledge and apply it to a new open subject.
- Be able to respect specifications and deadlines.
- Be Teacher for the quality of his work.
- Take a step back from his experience, gain confidence in professional integration.
- Know how to communicate about your work in writing and orally.

Hourly volumes in and out of the classroom. 24 weeks of full-time internship between March and the end of August.

Evaluation. Placement report (/35, about fifty pages excluding annexes), tutor evaluation (/30), oral defence (/35 , 25 minutes presentation, 25 minutes questions).

Teacher. Course managers, Mr. Y. Berthaud and Mrs H. Dumontet.