MASTER OF SCIENCE, TECHNOLOGY AND HEALTH

2024-2025

YEAR 2

MECHANICAL ENGINEERING

COMPUTATIONAL MECHANICS

PROGRAMME SUPERVISOR(S):
Patrick ROZYCKI

YEAR 2 - Autumn Semester

CORE COURSES

Course code	Title	ECTS Credits
CFDIF	Computational Methods for Incompressible Flows	4
CPLED	Numerical Methods for Simulation of Coupled Problems	4
CRASH	Crash and Impact	4
MODRED	Model Reduction	4
NUMUQ	Numerical Methods for Uncertainty Quantification	4
PMFLU	Physical Modeling of Fluids	4
XFEM	Extended Finite Element Method and Level Set Techniques	4

LANGUAGE COURSES

Course code	Title	ECTS Credits
CCE3	Cultural and Communication English	2
ESP3	Spanish Language	2
FLE3	French Language	2

YEAR 2 - Spring Semester

CORE COURSES

Course code	Title	ECTS Credits
THESIS	Master Thesis or Internship	30

Master Programme - Mechanical Engineering - Computational Mechanics

YEAR 2 - Autumn Semester

Computational Methods for Incompressible Flows [CFDIF]

LEAD PROFESSOR(S): Alban LEROYER

Requirements

Objectives

At the end of the course the students will have:
▪ knowledge and understanding of the basic elements needed to build a reliable numerical and physical modelling strategy for incompressible flow.
▪ an ability to understand the basic properties which must be fulfilled by the modelling strategies at continuous and discrete levels.
▪ an ability to understand the limitations and requirements of discretization methods needed to solve RANSE for high Reynolds flows around complex geometries.
▪ an ability to study independently; use library resources; use a personal computer for basic programming; effectively take notes and manage working time.

Course contents

This module presents the modelling strategies which are used to compute viscous incompressible flows by solving the Reynolds-Averaged Navier-Stokes Equations.
It covers mainly:
▪ a description of fully unstructured finite volume discretization strategies
▪ a study of coupling strategies to account for the incompressibility constraint and various pressure velocity coupling algorithms
▪ a description of a general face-based unstructured finite volume discretization
▪ a critical review of various applications ranging from shape optimization for ship hulls or aircraft wings and optimal flow control in aerodynamics

Course material

▪ Moukalled F. and Mangani L. and Darwish M., The Finite Volume Method in Computational Fluid Dynamics, Springer Verlag, 2016
▪ Peric and J. Ferziger., Computational Methods for Fluid Dynamics, Springer Verlag, 2002C.
▪ Hirsch, Numerical Computation of Internal and External Flows (Second Edition), Elsevier, 2007
▪ Peyret R., Handbook of Computational Fluid Mechanics, Academic Press, 1996.
▪ Marnet-CFD Best Practice Guidelines for Marine Applications of CFD: https://pronet.wsatkins.co.uk/marnet/guidelines/guide.html

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	18 hrs	0 hrs	0 hrs	4 hrs	2 hrs

Numerical Methods for Simulation of Coupled Problems [CPLED]

LEAD PROFESSOR(S): Alban LEROYER / Laurent STAINIER

Requirements

Objectives

At the end of the course the students will have:

- knowledge and understanding of: the challenges of coupled problems in numerical simulation, the broad classes of coupled problems, the different algorithmic approaches which are used in practice, their relative advantages and associated difficulties;
- an ability to: identify and classify coupled problems of various types, identify sources and mechanisms of coupling and their implication from a computational point of view; logically formulate an adapted algorithmic strategy for different practical coupled problems and translate the formulation to a practical computational approach using existing tools as much as possible; study independently; use library resources; solve coupled problems with existing finite element code(s).

Course contents

The course will present and discuss various computational approaches for the numerical simulation of coupled problems. The first part of the course will consider the problem from the abstract point of view of coupled systems. We will identify and describe:

- the various classes of coupled problems (weak vs. strong coupling),
- the various classes of algorithmic approaches (monolithic, staggered, sequential),
- the problems and difficulties linked to field transfer.

In the second part of the course, these concepts will be put into practice for two specific types of coupled problem.
Firstly, we will address thermo-mechanical problems. The different potential sources of coupling will be reviewed, as well as their implication from the computational point of view. The different algorithmic approaches will then be put into practice in project work for various thermo-mechanical problems (thermo-plasticity, thermo-visco-elasticity, shape memory alloys, etc).
Secondly, a focus will be made on Fluid-Structure Interaction, especially in hydrodynamics configuration where stabilisation issues occur due to added mass phenomenon. For this application, computer-based classes followed by a project using the industrial CFD suite Fine/Marine are provided to highlight the concepts learned during the lectures.

Course material

A selection of recent research papers on computational strategies for coupled problems will be used in the course. A good starting point is the following paper:
“Partitioned analysis of coupled mechanical systems”, C.A. Felippa, K.C. Park, C. Farhat, Comput. Methods Appl. Mech. Engrg. 190, 3247-3270, 2001.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

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

Crash and Impact [CRASH]

LEAD PROFESSOR(S): Patrick ROZYCKI

Requirements

Finite Element Method, Constitutive behaviour law, Plasticity

Objectives

Industrial safety issues, particularly in the area of transportation, require more precise knowledge of the behaviour of materials and structures subjected to rapid and dynamic loading.

This course aims to examine current practices and future trends in this field, with regard to mechanical, numerical and experimental aspects. The main concepts covered are materials modelling for dynamic loading (constitutive laws, strain rate sensitivity, experimental characterisation methods), crash design rules, numerical simulation (tools and integration schemes for the implementation of a model), and experimental methods to characterise structure behaviour.

The students will be able to identify the links between numerical model creation and experimental conditions, and examine the different problems related to each of these tools. This will enhance their critical thinking skills and increase their capacity to provide the best numerical/experimental correlations.

The students will undertake a project to consolidate the learning process: first, they will participate in a dynamic crushing tubes experiment. Then, they will have to provide a numerical model of the experiment. Finally, they will have to analyse the results and highlight the various problems at each step.

Course contents

1. Overview of shocks
   - Nature, type and classification of shocks

2 Crash in the field of transportation
   - Overview, safety, different approaches used

3. Numerical modelling
   - Constitutive laws, different time integration methods, non-linearities

4. Experimental devices
   - Description, different types of tests (front or side-impact)

5 Study of an analytical model for circular or square tubes

6 Simple case study
   - Experiment on a simple structure, numerical simulation and experimental/numerical correlations

Course material

N. Jones, Structural Crashworthiness, Cambridge University Press, 1997

Jorge A.C. Ambrósio, Manuel F.O. Seabra Pereira, F. Pina da Silva, Crashworthiness of Transportation Systems: Structural Impact and
Occupant, Springer Netherlands, 1997

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	4 hrs	0 hrs	28 hrs	0 hrs	0 hrs

Model Reduction [MODRED]

LEAD PROFESSOR(S): Jose-Vicente AGUADO

Requirements

Objectives

At the end of the course the students will have:

▪ knowledge and understanding of: the current difficulties encountered by standard incremental and mesh-based simulation techniques; proper orthogonal decomposition; separated representations for circumventing curse of dimensionality;
▪ ability to: identify the need for model reduction in problems taken for different areas of computational science and engineering; formulate reduced models for different kind of models identified in many areas: computational biology, computational mechanics, forming processes simulation, etc; develop simulation codes making use of model reduction; effectively take notes and manage working time.

Course contents

Numerous models encountered in science and engineering remain nowadays, despite the impressive progress recently attained in computational simulation techniques, intractable when the usual and well experienced discretization techniques are applied for their numerical simulation. Model reduction allows spectacular simulation speed-up, of several orders, and also solving models never until now solved (3D models involving extremely small-time steps and models suffering the so-called curse of dimensionality). The topics are organized as follows:

▪ A posteriori model reduction techniques, including the Proper Orthogonal Decomposition and the Reduced Basis method.
▪ Algebraic methods for matrices and tensors, including the Singular Value Decomposition and tensor formats.
▪ A priori model reduction techniques, and specifically, the Proper Generalized Decomposition method, for parametric problems, in-plane-out-of-plane separated representations and vector field problems.
▪ Applications in computational science and engineering.

Course material

▪ Lecture notes
▪ A dozen recent research papers in English on model reduction.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	20 hrs	0 hrs	0 hrs	4 hrs	0 hrs

Master Programme - Mechanical Engineering - Computational Mechanics

YEAR 2 - Autumn Semester

Numerical Methods for Uncertainty Quantification [NUMUQ]

LEAD PROFESSOR(S): Anthony NOUY

Requirements

Objectives

This course is an introduction to numerical methods for uncertainty quantification in computational science. At the end of the course the students will have knowledge and understanding of: challenges in uncertainty quantification in computational science; modelling and estimation of uncertainties; numerical methods to propagate uncertainties through a model; sensitivity analysis; methods for the construction of surrogate or reduced order models.

Course contents

The course addresses the following topics:
- probabilistic modelling and estimation of uncertainties
- propagation of uncertainties (monte-carlo methods, variance reduction, estimation of rare events)
- sensitivity analysis
- approximation of models and reduced order modelling

Course material

- R. Ghanem, D. Higdon, H. Owhadi (eds). Handbook of uncertainty quantification. Springer. 2017
- Sullivan, T. J. (2015). Introduction to uncertainty quantification (Vol. 63). Springer.
- R. Y. Rubinstein and D. P. Kroese. Simulation and the Monte Carlo method, volume~10. John Wiley & Sons, 2016.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	18 hrs	0 hrs	0 hrs	4 hrs	2 hrs

Master Programme - Mechanical Engineering - Computational Mechanics

YEAR 2 - Autumn Semester

Physical Modeling of Fluids [PMFLU]

LEAD PROFESSOR(S): Alban LEROYER

Requirements

Objectives

At the end of the course the students will have:

- knowledge and understanding of: the limitations of physical models, the evolution of physical models with respect to computational power.
- an ability to: chose an appropriate physical model for a given problem; set properly a CFD solver for standard physical configurations; analyse and review the numerical results; study independently; manage a numerical project on a computer

Course contents

This module is devoted to the analysis of the main physical modelling strategies used to compute viscous incompressible flows. It covers:

- an overview of the main turbulence closures used in high Reynolds incompressible flows ranging from statistical closures to Large Eddy Simulation models

Computers labs to put into pratices the constraints regarding the mesh generation and the influence of the turbulence modelling are delivered using the industrial CFD suite Fine/Marine.

- a review of the most recent cavitation models and an analysis of the underlying physics,
- a critical illustration of the predictive capabilities of these models for various experimental databases

Course material

- Lecture notes.
- D.C. Wilcox, Turbulence Modelling for CFD, DCW Industries, 2002
- C. Hirsch, Numerical Computation of Internal and External Flows (Second Edition), Elsevier, 2007
- Marnet-CFD Best Practice Guidelines for Marine Applications of CFD
- https://pronet.wsatkins.co.uk/marnet/guidelines/guide.html

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	14 hrs	0 hrs	6 hrs	2 hrs	2 hrs

Extended Finite Element Method and Level Set Techniques [XFEM]

LEAD PROFESSOR(S): Grégory LEGRAIN

Requirements

Objectives

At the end of the course the students will have:

▪ knowledge and understanding of the current difficulties encountered by the finite element method; the partition of unity to model surfaces for linear and non-linear problems; the level set technique to evolve surfaces; basic knowledge of non-linear finite elements for static and dynamics.
▪ an ability to: identify the need for extended finite elements and level sets in problems taken for different areas of mechanics; logically formulate a numerical approach using extended finite elements and level sets for different practical problems and translate the formulation to an existing extended finite element code; study independently; use library resources; use an existing extended finite element code; effectively take notes and manage working time.

Course contents

The course presents an extension of the finite element method known as, X-FEM, which is currently widely used in research and has started to appear in industry. This method basically eliminates the need to mesh physical surfaces (cracks, holes, material interfaces) in finite element computations. The surfaces are located and evolved by the level set technique which is also taught in the course. The topics are organized as follows:

▪ Overview of a wide class of problems that cannot be solved efficiently by the finite element method and necessity to extend the method.
▪ The keystones of the extended Finite Element Method: enrichment with the partition of unity and level set representation of surfaces.
▪ Industrial applications in fracture mechanics.
▪ Level sets and fast marching algorithms to evolve surfaces.

Course material

▪ Lecture notes provided
▪ Pommier, S., Gravouil, A., Combescure, A., & Moës, N. (2011). Extended finite element method for crack propagation. Wiley.
▪ Osher, S., Fedkiw, R., Level Set Methods and Dynamic Implicit Surfaces, Springer, 2003.

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	4	16 hrs	0 hrs	6 hrs	0 hrs	2 hrs

Cultural and Communication English [CCE3]

LEAD PROFESSOR(S): David TROYA

Requirements

Objectives

- Understand the fundamental principles of scientific writing and the importance of clarity and precision in communication.
- Structure scientific documents effectively, adhering to genre-specific conventions.
- Employ appropriate language and tone for diverse scientific audiences.
- Integrate and cite sources correctly to support research arguments and findings.
- Edit and revise their writing for coherence, style, and grammatical accuracy.
- Prepare and deliver scientific presentations, both written and oral.

Course contents

Introduction to Scientific Writing

Overview:

This course provides an essential foundation in scientific writing, equipping students with the skills necessary to effectively communicate research findings and scientific concepts. Through a combination of lectures, workshops, and practical assignments, students will learn the conventions of scientific writing, including structure, style, and clarity. The course will cover various types of scientific documents, such as research papers, literature reviews, grant proposals, and poster presentations.

Course Structure:

The course will be organized into weekly sessions that include lectures on theoretical concepts, hands-on writing exercises, peer review workshops, and discussions of exemplary scientific literature. Students will engage in collaborative projects and receive constructive feedback to enhance their writing skills.

Assessment:

Students will be assessed through a combination of assignments, including written documents, peer review participation, and presentations. Active participation in workshops and discussions is also required to foster a collaborative learning environment.

Course material

Hoogenboom BJ, Manske RC. How to write a scientific article. Int J Sports Phys Ther. 2012 Oct;7(5):512-7. PMID: 23091783; PMCID: PMC3474301.

Paré G, Kitsiou S. Chapter 9Methods for Literature Reviews. In: Lau F, Kuziemsky C, editors. Handbook of eHealth Evaluation: An Evidence-based Approach [Internet]. Victoria (BC): University of Victoria; 2017 Feb 27. Available from: https://www.ncbi.nlm.nih.gov/books/NBK481583/

How to Create a Research Poster. A guide fo creating a research poster. https://guides.nyu.edu/posters

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	2	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

Spanish Language [ESP3]

LEAD PROFESSOR(S): Marta HERRERA

Requirements

N/A

Objectives

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

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

Course contents

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

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

Course material

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

Assessment

Individual assessment: EVI 1 (coefficient 1)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
Spanish	2	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

Master Programme - Mechanical Engineering - Computational Mechanics

YEAR 2 - Autumn Semester

French Language [FLE3]

LEAD PROFESSOR(S): Silvia ERTL

Requirements

N/A

Objectives

The objective is to familiarize the learner with the French language and French culture through an entertaining task-based communicative language teaching, focused on speaking combined with:
- Phonetics
- Self-correcting exercises on our learning platform
- Learning Lab activities
- Project work
- Tutoring

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

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

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

Course contents

Two different tracks are proposed: track 1 for students newly arrived at Centrale Nantes and track 2 for students who have completed the first year of the French course. Track 1:
Full range of practical communication language exercises: reading comprehension, listening comprehension, written expression, oral expression.
Learners will be able to use the foreign language in a simple way for the following purposes:

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

2. Establishing and maintaining social and professional contacts, particularly:
- meeting people and making acquaintances
- extending invitations and reacting to being invited
- proposing/arranging a course of action
- exchanging information, views, feelings, wishes, concerning matters of common interest, particularly those relating to personal life and circumstances, living conditions and environment, educational/occupational activities and interests, leisure activities and social life

3. Carrying out certain transactions:

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

Track 2:
This track follows on directly from the first-year French course, developing and completing the concepts studied thus far. The main themes are: housing, health and work. These topics will help prepare students for their future work environment. For example, housing is explored in the form of a search for accommodation upon arrival in a new city. Special workshops for CVs and cover letters, elevator pitches and job interviews.

Course material

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

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	2	0 hrs	32 hrs	0 hrs	0 hrs	0 hrs

Master Thesis or Internship [THESIS]

LEAD PROFESSOR(S): Patrice CARTRAUD

Requirements

Objectives

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

Course contents

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

Course material

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

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
English	30	0 hrs	0 hrs	0 hrs	0 hrs	0 hrs