# Discipline Specifics Modules

## *ACOUSTIQUE ENVIRONNEMENTALE*

## ENVIRONMENTAL ACOUSTICS

**Lecturers:** Marie Annick GALLAND, Didier DRAGNA, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : MI

### Objectives

Noise is considered by the population as one of the main and most important nuisances. Taking into account acoustic constraints is therefore of primary importance in many fields, for example in building engineering or evaluation of transportation systems. This course presents basic notions in acoustics particularly suited to engineers working in related sectors. More specifically will be developed acoustics of rooms and industrial or public environments, outdoor sound propagation in an urban environment, as well as the various techniques used to control (usually reduce) sound levels: passive techniques (noise barriers, use of absorbing materials) or active ones (anti-noise). Subjective aspects will also be introduced with notions on sound perception, sound

Keywords : Acoustics, room acoustics, noise control, outdoor propagation, sound perception

### Programme

I- Basics of Acoustics
II- Sound perception: from deciBel scales to nuisances
III- Room acoustics: modal theory and energetic approach (Sabine theory, ray tracing, reverberation time and quality indices)
IV- Noise reduction and control: airborne sound insulation (single and double- leaf partitions), barriers, absorbing materials, active control
V- Outdoor propagation: effects of ground, buildings, meteorological conditions, … ; sound maps

### Learning outcomes

- Develop a coherent approach for diagnosing a problem in environmental acoustics
- Build a simplified model
- Propose a technical solution and evaluate the margin of error

### Independent study

Objectifs : Practical work:
- Room acoustics: measurement of reverberation time and sound quality indices in the cinema room of ECL; numerical simulation with CATT-Acoustic software.
- Outdoor propagation: Sound map design and analysis; numerical simulation

Méhodes :

### Core texts

A. Pierce, *ACOUSTICS, INTRODUCTION TO ITS PHYSICAL PRINCIPLES AND APPLICATIONS*, Mc Graw-Hill, 1981
H. Kutruff *ROOM ACOUSTICS*, Spon Press, 2000
D. Bies*ENGINEERING NOISE CONTROL*, Spon Press, 2009

### Assessment

Written Exam (50%); Practical work (50%)

## *ACOUSTIQUE GÉNÉRALE : SOURCES ACOUSTIQUES ET PROPAGATION DU SON*

## GENERAL ACOUSTICS : ACOUSTICS SOURCES AND SOUND PROPAGATION

**Lecturers:** Vincent CLAIR, Didier DRAGNA, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : MI

### Objectives

This advanced course of acoustics is focused on sources of sound and their propagation. The basics of acoustics, such as the linear acoustic equations and the quantitative evaluation of sound, are briefly presented before going further into the description of sources and their radiation in bounded or unbounded spaces. The sound radiated by vibrating structures and the acoustic propagation in inhomogeneous media are also discussed. The objective of the course is to provide the theoretical background required to approach a complex problem of sound generation and/or radiation. This course also provides a basis for students who might be interested in more specialised sub-domains of acoustics.

Keywords : Acoustics, sound waves, acoustic sources, acoustic radiation, duct acoustics, sound induced by vibrating structures, propagation in inhomogeneous media.

### Programme

I – Equations of linear acoustics (wave equation, acoustic energy, harmonic waves)
II – Plane and spherical waves, Boundary conditions, Surface impedance
III – Acoustic levels and spectral analysis (Decibels, power spectral density, weightings)
IV – Acoustic propagation in ducts (duct modes, cut-off frequency, low frequency models)
V – Sources (elementary sources, Green's function, source distribution)
VI – Radiation from vibrating structures (boundary integral equation, Rayleigh integral)
VII – Acoustic propagation in inhomogeneous media (geometrical and paraxial approximations)
VIII – Further elaborations (thermo-viscous absorption, diffraction by rigid bodies)

### Learning outcomes

- Understanding of sound generation and radiation in classical configurations.
- Modelling and resolution of an acoustics problem.
- Communicating with experts in acoustics.
- Acquiring a theoretical basis to approach a specialized domain of acoustics.

### Independent study

Objectifs :

Méhodes : Two practical work sessions: 1) Measurement of the acoustic power of a source in anechoic and reverberant rooms. 2) Duct propagation near a sudden change of section. A special lecture on source localisation with an industrial partner (MicrodB).

### Core texts

A. D. Pierce, *ACOUSTICS: AN INTRODUCTION TO ITS PHYSICAL PRINCIPLES AND APPLICATIONS*, The Acoustical Society of America, 1989
L. E. Kinsler et al. *FUNDAMENTALS OF ACOUSTICS*, John Wiley & Sons, 1982
D.T. Blackstock*FUNDAMENTALS OF PHYSICAL ACOUSTICS*, John Wiley & Sons, 2000

### Assessment

Final mark = 50% Knowledge + 50% Know-how
Knowledge grade = 100% final exam
Know-how grade = 100% continuous assessment

## *AÉRODYNAMIQUE ET ENERGÉTIQUE DES TURBOMACHINES*

## FUNDAMENTALS OF TURBOMACHINES

**Lecturers:** Alexis GIAUQUE, Pierre DUQUESNE

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : AN

### Objectives

The main objective of this course is to familiarize the students with the physical phenomena, mechanisms and basic computations behind turbomachinery flows.Starting with aerodynamics and thermodynamics applied to turbomachinery, we will detail the main tools used in the design of turbomachines. More specifically, we will tackle the design of an axial compressor given a specific efficiency objective.Practical work on a dedicated axial low-speed compressor test bench will be helpful to apprehend theoretical notions seen in class in a concrete case. Tutorial sessions will be devoted to the design of an axial compressor given specific objectives.

Keywords : turbomachines, compressor, turbine, aerodynamics, energetics, compressibility

### Programme

Range of operation of turbomachines
Characteristic curves (nominal point and range of operation)
Usage of integral formulations for the fluid dynamics equations applied to turbomachines.
Aero-thermodynamics analysis in 1D
Real transformations in turbomachines, computation of losses.
2D analysis in the circumferential plane: velocity triangles, load factors for compressors, correlations.
2D analysis in the meridional plane: radial equilibrium.
Introduction to unsteady and 3D phenomena

### Learning outcomes

- learn the operating rules of turbomachines
- know how to design an axial compressor
- master compressible aerodynamics
- know how to analyze turbomachinery flows

### Independent study

Objectifs : Design a subsonic axial compressor (in support of tutorial sessions)
Write a numerical program for the design of the compressor (matlab, python,...)

Méhodes :

### Core texts

N. A. Cumpsty, *COMPRESSOR AERODYNAMICS*, Longman Scientific & Technical, 1989
D Japikse, N. C. Baines *INTRODUCTION TO TURBOMACHINERY*, Concepts ETI, 1987

### Assessment

Final mark = 50% Knowledge + 50% Know-how
Knowledge = 100% Final exam
Know-how = 100% continuous assessment

## *AÉRODYNAMIQUE EXTERNE*

## EXTERNAL AERODYNAMICS

**Lecturers:** Jérôme BOUDET, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : AN

### Objectives

Lifting surfaces are used in aeronautics, but also for ground vehicles and energy production (wind). The aerodynamic design of these surfaces generally aims at optimizing the lift component of force, while minimizing drag. The objectives of the course are:
- Understand and model the forces (lift and drag) induced by the airflow on a body.
- Identify the associated parameters.
- Formulate and apply aerodynamic models.
- Estimate the accuracy of such models from a design perspective.

Keywords : Lift, Drag, Aeronautics, Automotive, Energy, Lifting Surfaces.

### Programme

1. Flight dynamics.
2. Two-dimensional wing design. Potential flow and singularity methods.
3. Lift and 3D effects. Models: lifting-surface and lifting-line theories.
4. Drag control.
5. Compressibility effects.

Laboratory class: study of an aerofoil in a wind tunnel and comparison with numerical simulations.
Tutorial class: modelling exercises.
Tutorial class: geometrical design of an aerofoil with given specifications.

### Learning outcomes

- Master the basic models of aerodynamics.
- Pre-design of lifting surfaces in aerodynamics.
- Understand the basic principles of aircraft flight.

### Independent study

Objectifs : Completion of the laboratory and tutorial work.

Méhodes :

### Core texts

E.L. Houghton , P.W. Carpenter, *AERODYNAMICS FOR ENGINEERING STUDENT*, Butterworth-Heinemann, 2003
D.P. Raymer *AIRCRAFT DESIGN: A CONCEPTUAL APPROACH*, AIAA, 2012
B.W. McCormick*AERODYNAMICS, AERONAUTICS AND FLIGHT MECHANICS*, Wiley, 1994

### Assessment

Final mark = 55% Knowledge mark + 45% Know-how mark
Knowledge mark = 100% final exam
Know-how mark = 100% continuous assessment (laboratory and tutorial reports)

## *ALÉAS ET HÉTÉROGÉNÉITÉS DANS LES STRUCTURES*

## UNCERTAINTIES AND HETEROGENEITIES IN REAL STRUCTURES

**Lecturers:** Francesco FROIIO, Eric VINCENS

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

Keywords :

### Programme

### Learning outcomes

### Independent study

Objectifs :

Méhodes :

### Core texts

J.-A. Calgaro, *INTRODUCTION AUX EUROCODES : SÉCURITÉ DES CONSTRUCTIONS ET BASES DE LA THÉORIE DE LA FIABILITÉ*, Presses de l'École Nationale des Ponts et Chaussée, 1999
R. Park, T. Paulay *REINFORCED CONCRETE STRUCTURES*, John Wiley & Sons, 1975
Y. Sieffert*LE BÉTON ARMÉ SELON LES EUROCODES 2*, Dunod, 2010

### Assessment

## *ANALYSE DES ASSEMBLAGES : GÉOMÉTRIE ET ARCHITECTURE*

## MECHANICAL ASSEMBLY: ARCHITECTURE AND GEOMETRY ANALYSES

**Lecturers:** Didier LACOUR, Bertrand HOUX

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : FR

### Objectives

Present methods and tools for analyzing the geometric quality of assemblies.
Mastering the architecture and geometry of assemblies is a major industrial objective. The geometrical quality of the parts and the architecture of the assemblies can have direct repercussions on the assembly capacity of the product, but also on the services it must provide.
This course presents the modern methods of assembly simulation by integrating the geometrical defects of their components. It thus identifies the theoretical concepts on which these methods are based, in order to understand their fields of application and their limits.

Keywords : Assembly, architecture, geometric specifications, ISO GPS standards, tolerancing, metrology, influencing analysis, assembly simulation, statistics

### Programme

Quantification of the specifications and analysis of their influences on the assembly (sensitivities) by torsors of small displacements.
Statistical Approaches, Monte Carlo.
Geometric Specification Methods, Geometrical Product Specification (GPS).
Algorithms used in three-dimensional metrology (numerical methods of association).

### Learning outcomes

- Knowledge of methods and tools for analyzing the geometric quality of assemblies. Write and interpret standardized geometric specifications. Analyze influences and contributions on a concrete model. Establish and implement a three-dimensional control strategy.

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

Anselmetti B. - Lavoisier, 2010., *TOLÉRANCEMENT – VOLUMES 1 À 4.*, Hermès, 2010
Charpentier F. *MÉMENTO DE SPÉCIFICATION GÉOMÉTRIQUE DES PRODUITS – LES NORMES ISO-GPS.*, AFNOR, 2015
Bourdet P. & Mathieu L.*TOLÉRANCEMENT ET MÉTROLOGIE DIMENSIONNELLE.*, Cetim, 1999

### Assessment

Final mark = 60% Knowledge + 40% Know-how
Knowledge mark = 100% final exam
Know-how mark = 100% continuous assessment

## *APPRENTISSAGE PROFOND & INTELLIGENCE ARTIFICIELLE : UNE INTRODUCTION*

## DEEP LEARNING & ARTIFICIAL INTELLIGENCE : AN INTRODUCTION

**Lecturers:** Emmanuel DELLANDREA, Alberto BOSIO, Alexandre SAIDI, Céline

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : MI

### Objectives

By making possible breakthroughs supposed to be impossible until recently in a growing number of domains, e.g., computer vision, natural language processing, autonomous driving or games, deep learning has revolutionized the artificial intelligence domain that has become one of the major pillars of our society. In this course, our goal is to introduce the basis of concepts and technics in deep learning

Keywords : Deep learning, artificial intelligence, supervised learning, reinforcement learning, PyTorch

### Programme

- Introduction to machine learning and deep learning
- Classification/regression and gradient descent
- Computational graphs & backpropagation
- Training deep neural networks
- Convolutional Neural Networks (CNN)
- CNN Architectures
- Deep reinforcement learning (Actor, Critic, Actor-Critic)
- Embedded Deep Learning

### Learning outcomes

- Understanding the principles of deep learning
- Mastering fundamental techniques for supervised learning and reinforcement learning
- Being able to deploy a deep learning approach with the PyTorch framework

### Independent study

Objectifs : The principles of deep learning introduced in the course will be implemented during three practical sessions using the PyTorch framework and a GPU card for embedded applications

Méhodes : use of PyTorch

### Core texts

Ian Goodfellow, Yoshua Bengio, Aaron Courville., *DEEP LEARNING*, MIT Press, 2016
Bert Moons, Daniel Bankman, Marian Verhelst *EMBEDDED DEEP LEARNING ALGORITHMS, ARCHITECTURES AND CIRCUITS FOR ALWAYS-ON NEURAL NETWORK PROCESSING*, Springer, 2019
Richard S. Sutton, Andrew G. Barto.*REINFORCEMENT LEARNING: AN INTRODUCTION (2ND EDITION)*, MIT Press, 2018

### Assessment

50% written exam, 50% evaluation of the assignments

## *AUTOMATIQUE AVANCÉE*

## ADVANCED CONTROL

**Lecturers:** Anton KORNIIENKO, Xavier BOMBOIS

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : MI

### Objectives

For increasingly complex systems and increasingly tighter and contradictory performance specifications, the design of a controller achieving the best trade-off between these specifications must be tackled via an optimization problem. In LQ/LQG control, these specifications are recast into a criterion reflecting the trade-off between control performance and its cost. The drawback of this approach is that control performance can only be guaranteed if the model used for the design is an accurate representation of the system. The necessary robustness of the controller can be ensured via H-infinity control, a generalization of classical frequency domain control. These two control approaches will be presented and compared. Examples will allow the students to use

Keywords : LQ/LQG control, H2 control, Robust Control, H-infinity control, multivariable control.

### Programme

The course will start by a recap on classical control methods and classical control performance specifications. We will then present the LQ/LQG control design approach and its generalization i.e. H2 control. Attention will be paid to the additional performance specifications that can be tackled with this specific control design method and to the different ways to achieve this control action (input-output approach or state-feedback with observer structure). Finally, the second advanced control design method (H-infinity control) will be presented. This method allows dealing with similar performance specifications as LQ/LQG control, but can also tackle the robustness issues related to model uncertainty.

### Learning outcomes

- To be able to specify an optimization criterion for LQ/LQG control and for H-infinity control based on a list of performance specifications.
- To be able to design a controller using an advanced control method.
- To be able to analyze the achieved closed-loop system and its control performance.

### Independent study

Objectifs :

Méhodes :

### Core texts

Alazard D., Cumer C., Apkarian P., Gauvrit M. et Ferreres G., *ROBUSTESSE ET COMMANDE OPTIMALE*, Cépaduès editions, 1999
Kwakernaak H. *H2-OPTIMIZATION – THEORY AND APPLICATIONS TO ROBUST CONTROL DESIGN*, Annual Reviews in Control, 26 (1), pp. 45-56, 2002
Skogestad S. and Postlethwaite I. *MULTIVARIABLE FEEDBACK CONTROL, ANALYSIS AND DESIGN*, John Wiley and Sons Chischester, 2005

### Assessment

Final mark = 50% Knowledge +50% Know-how
Knowledge = 100% final exam + 0% continuous assessment
Know-how = 0% final exam + 100% continuous assessment

## *BRUITS D'ORIGINE AÉRODYNAMIQUE*

## AERODYNAMICALLY GENERATED SOUND

**Lecturers:** Michel ROGER, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : MI

### Objectives

The course is aimed at giving the students a general background in aeroacoustics, the science of aerodynamically generated sound. This includes the physical understanding of underlying mechanisms, their experimental study and associated analytical modeling. Students will be able to address modern problems of engineering interest and to take up international scientific publications. Basic notions of general acoustics and fluid dynamics will be reminded. Many practical case studies will be presented, dealing with aeronautical and ground transports, heating, ventilation and air conditioning, wind turbines and wind-induced noise.

Keywords : Acoustics, aeroacoustics, aerodynamics, propulsion, aerinautics,fluid dynamics

### Programme

1 - Fundamentals and applications :
- Oscillatory motions in a gas and aerodynamic noise
- Acoustic analogies, wave equations and solving by the Green's function technique
- Sound radiation from moving sources
- Jet noise
- Tonal noise from self-sustained oscillations
- Wind noise on mechanical structures (truss, building exo-structures ...)
- Unsteady aerodynamics and noise from airfoils, high-lift devices

### Learning outcomes

- Ability to identify basic aeroacoustic mechanisms in complex systems
- Ability to reduce a basic mechanism to a simple mathematical model
- Ability to understand and identify the acoustic signature of an unsteady flow
- Ability to perform in dimensional analysis

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

Goldstein, M.E., *AEROACOUSTICS,* , McGraw-Hill, 1976
Glegg, S. & Devenport, W. *AEROACOUSTICS OF LOW-MACH NUMBER FLOWS*, Academic Press, 2017

### Assessment

The evaluation includes:
- an exam of 2h (all documents authorized, English and French versions f),
- reports on a case study and on 2 lab courses.

## *CARACTÉRISATION DES SURFACES ET DES NANOSTRUCTURES*

## CHARACTERIZATION OF SURFACES AND NANOSTRUCTURES

**Lecturers:** Fabrice DASSENOY, Maria-Isabel DE BARROS BOUCHET

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : FR

### Objectives

Nanotechnologies are concerned with a very divided state of matter and an exacerbated role of the surfaces compared to the volume. The physicochemistry and the chemistry of the exposed surfaces are very important for applications. The first atomic layers present on the solids are particularly reactive in many processes.This course proposes the study of the main techniques of characterization of surfaces and of low dimensionality structures. It will be illustrated by specific applications in the field of nanotechnology and biology.

Keywords : Surfaces, Interfaces, Nanostructures, Surface analyses, Electron microscopies, Electron spectroscopies

### Programme

I - Chemical analysis of the surface of solids.
Electron spectroscopies (photoelectron, Auger), ion spectroscopy (ToF-SIMS).
Information on surface chemical bonds.
II- Morphological analysis of the surface at a subnanometric scale.
Near-field microscopies (Tunneling microscopy, Atomic Force Microscopy, near-field optical microscopy) tunneling spectroscopy, measurement of interaction forces. Illustrations: (reconstruction of surfaces, single molecule, photonic crystals ...)
III - Characterization of interfaces.
Analytical Transmission Electron Microscopy, electron diffraction, X-ray analysis and

### Learning outcomes

- To know how to refer to good characterization techniques for the study and analysis of surfaces and nanostructures
- To know the basic principle of the main techniques of characterization of surfaces and nanostructures

### Independent study

Objectifs :

Méhodes :

### Core texts

R. W. Cahn. , *MATERIALS SCIENCE AND TECHNOLOGY : A COMPREHENSIVE TREATMENT.* , WILEYVCH, 1994

### Assessment

Two-hour test.

## *CHANGEMENT CLIMATIQUE*

## CLIMATE CHANGE

**Lecturers:** Pietro SALIZZONI, Alexandre SAIDI, Louis GOSTIAUX, Richard PERKINS

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : AN

### Objectives

While there is now a consensus that climate change is accelerating, there is still no agreement on measures to mitigate it. The reduction in emissions of
greenhouse gases is occuring too slowly to prevent global warming. The consequences of climate change will therefore affect almost all aspect of our lives and they will have to be taken into account in projects in all fields of engineering. It will probably also be necessary to consider intervening directly in climate processes, at planetary scale, and various strategies have already been proposed. The objective of this course is to provide a general understanding of the physics of climate change and of the related issues. It will provide future

Keywords : Climate change, greenhouse gases, carbon, paleoclimatology, warming, oceans, atmosphere, meteorology, modeling, dynamical systems

### Programme

Introduction: Definition of climate, main processes, evidence of recent climate changes
Radiative transfers: Solar radiation, the atmosphere as a filter, aerosols and clouds
Radiative forcing, Climate sensitivity, feedbacks
Atmospheric and oceanic circulation
Climate reconstruction: metrology, the history of the climate
Carbon cycle: Mechanisms of carbon transfer, capture and storage in the climate system
Climate modelling: assumptions, input data, results, sensitivity
Possible scenarios: Influence of different processes, regional climate change

### Learning outcomes

- Understand the notion of climate, and the physical processes that contribute to its definition
- Critically understand the factual elements available on climate changes
- Understand how climate models are formulated, and on which assumptions and data they rely on
- Identify the possible and probable consequences (physical, economic and political) of the climate change

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

G. K. Vallis, *ESSENTIALS OF ATMOSPHERIC AND OCEANIC DYNAMICS*, Cambridge University Press, 2019
D. Archer *THE GLOBAL CARBON CYCLE*, Princeton University Press, 2010
M. L. Bender*PALEOCLIMATE*, Princeton University Press, 2013

### Assessment

Final mark = 50% Knowledge + 50% Know-how
Knowledge = 100% final exam
Know-how = 100% Reports on the 3 tutorials

## *COMBUSTION POUR LA PROPULSION*

## COMBUSTION

**Lecturers:** Alexis GIAUQUE

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : AN

### Objectives

Combustion is a phenomenon that transforms the chemical potential energy contained in the fuel into thermal energy. The objective of this course is to understand the phenomena of combustion. A particularly targeted point of application concerns aeronautical turbojets. We will see what are the essential kinetic mechanisms of combustion, we will try to understand the physics of premix and diffusion flames, and how to stabilize these flames. We will focus on the turbulent regimes of these flames. Then we will discuss the acoustics in the aeronautical chambers. We will also study the physics of combustion of sprays. The simulation in the aeronautical chambers is the final goal.

Keywords : Combustion, Fluid Mechanics and Transfers, Explosions, Turbulent Mixing, Sprays, Chemical Kinetics, Energetics

### Programme

1. Introduction to aeronautical combustion
2. Essential kinetic mechanisms of combustion and the formation of polluting emissions
3. 0-D approach - perfectly and partially premixed reactors (PSR and PaSR) - transport / chemistry interaction, turbulent mixing / chemistry
4. Propagation of laminar and turbulent premix flames
5. Laminar and turbulent diffusion flames, flame stabilization
6. Formation, dynamics, combustion of sprays, models and experimental observation
7. Linear acoustics in combustion chambers, instabilities in combustion
8. Numerical modeling of combustion for an aeronautical engineer.

### Learning outcomes

- Know how to use mass and energy balances in practical reactive cases
- Know how to express (i) the kinetic terms in the local fluid mechanics balance equations, and (ii) the applicable simplifying assumptions
- Know the peculiarities of turbulent, diffusion and premixing flames
- Know how to analyze the stability of a turbulent flame in a turbojet

### Independent study

Objectifs : Several Numerical Design Sessions (BE) will be given and involve a part of group work and autonomy.

Méhodes :

### Core texts

R. Borghi et M. destriau, *LA COMBUSTION ET LES FLAMMES*, Editions Technip, 1995
K.K. Kuo *PRINCIPLES OF COMBUSTION*, Wiley-Interscience Publication, 2005
C K. Law*COMBUSTION PHYSICS*, Cambridge University Press, 2006

### Assessment

Final mark = 50% Knowledge + 50% Know-how
Knowledge = 100% Final exam
Know-how = 100% continuous assessment

## *COMPORTEMENT DES MATÉRIAUX*

## MECHANICAL BEHAVIOR OF MATERIALS

**Lecturers:** Vincent FRIDRICI, Thierry HOC

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : FR

### Objectives

Keywords :

### Programme

### Learning outcomes

### Independent study

Objectifs :

Méhodes :

### Core texts

J. Lemaître, J.-L. Chaboche, A. Benallal, R. Desmorat., *MÉCANIQUE DES MATÉRIAUX SOLIDES.*, Dunod, 2009
D. François, A. Pineau, A. Zaoui. *COMPORTEMENT MÉCANIQUE DES MATÉRIAUX : VOLUMES 1 ET 2*, Lavoisier, 2009
Michel Dufour, Karine Langlois, Michel Pillu, Santiago Del Valle Acedo*BIOMÉCANIQUE FONCTIONNELLE*, Elsevier Masson, 2017

### Assessment

## *DÉFIS INFORMATIQUES DU BIG DATA*

## COMPUTING CHALLENGES OF BIG-DATA

**Lecturers:** Stéphane DERRODE, Alexandre SAIDI, Céline HARTWEG-HELBERT

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

In many scientific fields, such as biology or environmental sciences, the rapid evolution of scientific instruments as well as the intensive use of computer simulation have led, in the last few years, to an important production of data. Scientific applications are confronted with new problems mainly related to the storage and exploitation of these data.
The teaching will allow us to discover the major problems raised by the emergence of these data flows (storage, interrogation, analysis and visualization), and to approach certain technological solutions currently proposed. The ethical and legal issues raised by the collection and exploitation of these data will also be examined.

Keywords : Big Data, Data scientist, NoSQL, Hadoop, Big Data analytics, Open Data, Linked open data

### Programme

- Big Data: an introduction to the issues, perspectives and applications
- The problem of large databases (NoSql, NewSql)
- Big Data and business model: the case of intermediation
- Open Data: open public data
- Big-Data Analytics: the basics of analyzing large volumes of data
- Data representation and visualization
- Three BEs on visualization, on Apache/Hadoop and on the web of data (SparQL).

### Learning outcomes

• Upon completion of this MOS, students will be able to: - To know the issues, opportunities and ethical problems raised by big-data. - Create simple Hadoop/Map-Reduce programs to exploit distributed data. - Manipulate NoSql databases using a modern DBMS (e.g. Mongo-Db).

### Independent study

Objectifs : Writing of a review on a big data theme, by groups of 3 to 6 students

Méhodes :

### Core texts

Philippe Lacomme, *BASES DE DONNÉES NOSQL ET BIG DATA : CONCEVOIR DES BASES DE DONNÉES POUR LE BIG DATA : COURS ET TRAVAUX PRATIQUES*, Ellipses, 2014
Viktor Mayer-Schönberger *BIG DATA : LA RÉVOLUTION DES DONNÉES EST EN MARCHE*, R. Laffont, 2014
Srinath Perera*HADOOP MAPREDUCE COOKBOOK : RECIPES FOR ANALYZING LARGE AND COMPLEX DATASETS WITH HADOOP MAPREDUCE* , 2013

### Assessment

Grade = 50% knowledge + 50% know-how
Knowledge grade = 100% final exam
Know-how mark = 50% bibliographic synthesis + 50% report on BE

## *DIAGNOSTIC ET SÛRETÉ DE FONCTIONNEMENT*

## DIAGNOSIS AND HEALTH MONITORING

**Lecturers:** Emmanuel BOUTLEUX, Catherine MUSY, Olivier ONDEL

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

To detect failure before they appear is a big challenge for any kind of complex systems. From modern car full of automation (sensors, actuators, control/command strategies) to more-electric airplanes, from industrial power plant to robotics applications, methods are needed to inform that a failure or default as appeared, appears or will appear.
That course will focus on automatic detection methods based on model-based approaches or artificial intelligence approaches.

Keywords : Diagnosis, health monitoring, identification, pattern recognition,FMECA

### Programme

Context
Fonctional approches like FMECA (Failure Modes, Effects and Criticality Analysis)
Reliability
Diagnosis approaches:
- model-based
  - identification
  - error detection
- artificial intelligence
  - pattern recognition

### Learning outcomes

- To realise challenges and difficulties associated with health monitoring
- To be able to applied pattern recognition techniques
- To be able to properly identify mathematical model for diagnosis purposes
- To be able to select parameters identification methods

### Independent study

Objectifs :

3 times 4h BE using Matlab (good knowledge of Matlab is a must)

Méhodes :

### Core texts

Bernard Dubuisson, *DIAGNOSTIC, INTELLIGENCE ARTIFICIELLE ET RECONNAISSANCE DES FORMES*, Hermès Science Publications, Collection : ic2 prod, 2001
Bernard Dubuisson *DIAGNOSTIC ET RECONNAISSANCE DES FORMES*, Traité des nouvelles technologies. Série diagnosti, 1990
Alain Villemeur*SÛRETÉ DE FONCTIONNEMENT DES SYSTÈMES INDUSTRIELS*, Edition Eyrolles, 1988

### Assessment

Final mark = 50% Knowledge + 50% Know-how
Knowledge = final exam
Know-how = average mark issued from 3 reports from BE

## *DURABILITÉ DES MATÉRIAUX ET DES STRUCTURES*

## DURABILITY OF MATERIALS AND STRUCTURES

**Lecturers:** Bruno BERTHEL, Michelle SALVIA

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : AN

### Objectives

In order to develop efficient, reliable and safe products, it is necessary to take into account the damage mechanisms of materials and parts. The topic of this course is how to predict the failure of materials under mechanical loading, taking into account the surrounding, in the field of carriage. Each class of materials having different failure process, damage mechanisms of each one are studied and formalized. This course contains theoretical lectures (fracture mechanics, fatigue,...) and practical works (fractography, acoustic emission,.. ).

Keywords : Fatigue, Fracture mechanics, Finite element method, Fractography, Acoustic emission.

### Programme

Fracture mechanics: material features, stress singularities and energetic criteria.
Fatigue of materials: fatigue and endurance domains, factors affecting fatigue life, design against fatigue and crack growth rate laws.
Multiaxial fatigue: definition and criteria.
Specificity of polymer and composite materials
Practical work on fractography: study of the fracture surfaces of parts and determination of the cause of failure.
Practical work on the interest of the acoustic emission in the field of structural health monitoring

### Learning outcomes

- Identify the different modes of damage and failure of materials used in the field of transportation and know how to analyze a fracture surface.
- Master the basics of fracture mechanics and material fatigue. Know how to use predictive tools for multiaxial fatigue life.
- To know the specificities of composite materials and to have notions on the monitoring of the state of structures (in particular acoustic emission).
- Use acquired knowledge to analyze a research problem and make a critical analysis.

### Independent study

Objectifs : Assignments consist of preparing practical works, writing reports and analyzing a scientific article. All these activities are teamwork.

Méhodes :

### Core texts

Dietmar Gross and Thomas Seelig, *FRACTURE MECHANICS*, Springer, Berlin, Heidelberg, 2011
Jaap Schijve *FATIGUE OF STRUCTURES AND MATERIALS*, KLUWER ACADEMIC PUBLISHERS, 2004
D. Hull and T. W. Clyne*AN INTRODUCTION TO COMPOSITE MATERIALS*, Cambridge University Press, 1996

### Assessment

Final mark = 50% "Knowledge" + 50% "Know-how"

"Knowledge" = 100% oral presentation

## *DYNAMIQUE DES STRUCTURES*

## STRUCTURAL DYNAMICS

**Lecturers:** Olivier DESSOMBZ, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : FR

### Objectives

The dynamic analysis of structures using modal synthesis and finite element methods has found a large number of industrial applications (aeronautics, automotive, shipbuilding, rail, civil engineering). The main goal of this course is to present these methods in a general framework by carrying out in parallel and in interaction a numerical approach and an experimental approach based on vibratory tests. Model correction and the influence of damping are also discussed.

Keywords : Finite elements - modeling - numerical methods - numerical modal analysis - substructuring - modal synthesis - damping

### Programme

- Discretization by finite elements
- Modification of the global matrix formulation
- Standard conservative problem
- Spectral problem
- Temporal integration of the transient problem
- Modeling of damping
- Identification of the damping matrices
- Modal synthesis, Sub-structuring
- Disturbance of dynamic models

### Learning outcomes

- Model a finite element structure
- Use a general industrial finite element calculation code
- Understand the foundations of finite element methods
- Implement vibration measurements

### Independent study

Objectifs : Finalize the TP and BE, write the reports

Méhodes :

### Core texts

J.-.F. IMBERT, *ANALYSE DES STRUCTURES PAR ÉLÉMENTS FINIS (3ÈME ED)*, Cepadues, 1995
M. GERARDIN, D. RIXEN *THÉORIE DES VIBRATIONS*, Masson, 1996
L. MEIROVITCH*COMPUTATIONAL METHODS IN STRUCTURAL DYNAMICS*, Sijthoff Nordhoff, 1980

### Assessment

Score = 50% knowledge + 50% know-how
Knowledge score = final exam
Know-how score = continuous assessment

## *DYNAMIQUE DES SYSTÈMES BIOLOGIQUES HUMAINS*

## DYNAMICS OF BIOLOGICAL HUMAN SYSTEMS

**Lecturers:** Didier DRAGNA, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

The human body is an extraordinary complex dynamic system, whose physical modeling is essentialy multidisciplinary. A large number of regulatory process aim at constantly monitoring the internal environement of the body, what is referred to as the homeostasis. In this course, physical modeling of human biologogical systems are presented. Some current applications in bioengineering (artificial heart, medical robotics and imaging) are introduced.

Keywords : biomechanics, heart, biological system, artificial heart, imaging

### Programme

Neuro-musculoskeletal system: strength of materials, rigid and flexible multibody systems, biomaterials..
Cardiovascular system: heart mechanics, circulation, network analysis, articial heart.
Medical robotics
Medical imaging: inverse problems, non-destructive testing, ultrasounds, X-rays, MRI.

Activities: Simulation of the motion with a multibody model. Signal processing for an electrocardiogram. Oral presentation and report on a research article.

### Learning outcomes

- Bridging your basic multi-disciplinary training with biomedical engineering.
- Acquire fundamental knowledge in biomedical engineering to master recent and future applications.
- Be able to interact with healthcare professionals on program topics.

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

D. A. Neumann, *KINESIOLOGY OF THE MUSCULOSKELETAL SYSTEM. FOUNDATIONS FOR PHYSICAL REHABILITATION.*, McGraw-Hill, 2002
L. Waite *BIOFLUID MECHANICS IN CARDIOVASCULAR SYSTEMS.*, McGraw-Hill, 2006
C. Guy, D. Ffytch*INTRODUCTION TO THE PRINCIPLES OF MEDICAL IMAGING.*, Imperial College Press,, 2005

### Assessment

Final mark = 0.5*Knowledge + 0.5*Know-how
Knowledge = final exam
Know-how = 0.5*written reports of BE + 0.5*oral and written presentation of a scientific

## *ENERGIE NUCLÉAIRE*

## NUCLEAR ENERGY

**Lecturers:** Anne-Segolene CALLARD

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

Nuclear energy represents a great technological and economic area, covering multidisciplinary skills and various jobs (project management, engineering,safety, ...). This module, that favours an industrial approach aims to give students both scientific and technical training in the various fields of nuclear energy. A wide part will be devoted to the study of current nuclear power reactors. This course will also provide an overview of the solutions to answer nuclear safety and people protection. It will be largely provided by experts in the field (Framatome, EDF).

Keywords : Nuclear reactors, nuclear power plants, nuclear safety.

### Programme

Basis of nuclear physics.
Basis of neutronics.
Reactor kinetics.
Current nuclear reactor plants: Operation and control.
Nuclear safety.
Fuel cycle.
Materials for nuclear engineering.

### Learning outcomes

- Identify the scientific, economic and environmental challenges of nuclear power.
- Explain the neutron cycle in a thermal neutron reactor and the concept of criticality
- Explain the principles of operation of a PWR
- Understand and explain nuclear safety issues

### Independent study

Objectifs : Study on future generation nuclear reactors.

Méhodes : Team work and oral restitution

### Core texts

John R. LAMARSH, *INTRODUCTION TO NUCLEAR ENGINEERING*, Addison Wesley Publishing company, 2013
Paul BONCHE *LE NUCLÉAIRE EXPLIQUÉ PAR DES PHYSICIENS*, EDP Sciences, 2002
Jacques LIGOU*INTRODUCTION AU GÉNIE NUCLÉAIRE*, Presses polytechniques et universitaires romandes, 1997

### Assessment

Score = 60% knowledge + 40% know-how
Knowledge score = final exam
Know-how score = BE mark (work + oral restitution)

## *ENERGIE STOCKAGE-CONVERSION*

## ENERGY, STORAGE, CONVERSION

**Lecturers:** Jean-Pierre CLOAREC

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

This course is a synthesis of all the physical phenomena used for energy storage and conversion. For every 2 hours lecture, a specialist from ECL presents the fundamental phenomena of a field: batteries, thermal solar, solar photovoltaic, electromechanical conversion, energy and radiation, combustion, bioenergy. Matter stores energy in various forms. Energy density, capacity to store and dispense energy depends on the nature of the energy conversion implemented: weak, nuclear, electromagnetic, gravitation... The cycles and transformation processes allowing the conversions and exchanges of energy will be studied emphasizing the engineering linked to the particularly renewable energies (solar, wind, biomass). This course provides a better vision of the

Keywords : energy; renewables; energy density; transformation processes; energy conversion and exchange; storage techniques; solar; batteries; nuclear; wind; gravity; radiation;

### Programme

-Synthesis on the different forms of energy and the associated orders of magnitude of energy density in matter
-solar; batteries and electrochemical storage; electromechanical conversion; electromagnetic conversion; combustion; bio-energy

### Learning outcomes

- Systemic approach: model an energy system based on several disciplines, identifying the couplings between disciplines.
- Systemic approach: argue and discuss the choices made to design a complete energy system. Question the relevance of the validation criteria.
- Implement positive interactions within the mini-project team
- Carry out a state-of-the-art study on an open problem on technical-scientific-economic issues related to an energy need. Formalize the outcome. Demonstrate a broad vision taking into account technological, economic, human and environmental issues.

### Independent study

Objectifs : Mobilize the concepts discussed in class and engineering sciences on concrete cases with scientific, technical and economic issues.
Practice dimensioning of renewable energy systems.

Méhodes : Group work on case studies chosen by students among a list or possibily proposed by students

### Core texts

Roger Balian, *LES MULTIPLES VISAGES DE L'ÉNERGIE*, Ecole d'été de Physique sur l'énergie , 2001
CEA (ouvrage collectif) *MEMENTO SUR L'ÉNERGIE « ENERGY HANDBOOK »*, CEA, 2015

### Assessment

Mark=50% knowledge + 50% know-how

## *EQUATIONS DIFFÉRENTIELLES STOCHASTIQUES ET MÉTHODES NUMÉRIQUES*

## STOCHASTIC DIFFERENTIAL EQUATIONS AND PROBABILISTIC NUMERICAL METHODS

**Lecturers:** Marie-Christophette BLANCHET, Alexandre SAIDI, Céline HARTWEG-

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : AN

### Objectives

This course deals with modelisation using time continous processes. The goal is to present both theoritical and pratical aspects on stochastic differentiale equations. The second part deals with numerical method to simulate stochastic processes. It is more specifically for students of Mathematic, Actuarial and quantitative finance
options and Masters. It is requiered to have followed a course on theory of probability (for example the course in S8 in Ecole Centrale de Lyon)

Keywords : Brownian Motion, Martingales, Ito calculus, Numerical simulations, Monte Carlo Markov chain methods

### Programme

1. Mouvement Brownien, intégrale d'Ito processus de diffusion, EDS
2. Méthodes de Monte Carlo, important sampling, réduction de variance
3. Simulation de processus aléatoires (EDS, quantification, autres ?)
4. MCMC, Metropolis Hasting et autres Gibbs

### Learning outcomes

- Modelisation with a stochastic differential equation
- Ito calculus
- Approximation of a diffusion. Practical aspects
- Gibbs algorithme or annealing method; Practical aspects

### Independent study

Objectifs :

Méhodes : Preparatory works on BE's problems

### Core texts

Francis Comets et Thierry Meyre. ., *CALCUL STOCHASTIQUE ET MODÈLES DE DIFFUSIONS.*, Série Mathématiques pour le Master/SMAI, Dunod, 2006
Nicole El Karoui et Emmanuel Gobet. *LES OUTILS STOCHASTIQUES DES MARCHÉS FINANCIERS*, Editions de l'Ecole Polytechnique, 2011
Bernard Bercu et Djalil Chafaï*MODÉLISATION STOCHASTIQUE ET SIMULATION*, Série Mathématiques pour le Master/SMAI, Dunod, 2007

### Assessment

Final mark =60% Knowledge + 40% Know-how
Knowledge= 100% final exam
Know-how= 100% continuous assessment

## *GÉNIE DE L'OCÉAN ET DU LITTORAL*

## COASTAL AND OCEAN ENGINEERING

**Lecturers:** Richard PERKINS

| Lecturers : 16.0 | TC : 0.0 | PW : 4 | Autonomy : 0.0 | Study : 8 | Project : 0.0 | Language : AN

### Objectives

The aim of this course is to provide a physical understanding of the basic processes involved in Ocean and Coastal engineering. The first part of the course addresses the dynamics of surface waves and the second part applies this to interaction with structures and with the sea bed.

Keywords : Ocean, coastline, waves, currents, tides, fluid-structure interaction, sediment transport, offshore engineering, coastal protection

### Programme

1. Introduction
The composition and physico-chemical properties of the oceans - stratification and vertical stability - Ocean currents and their interaction with the seabed and the atmosphere -tides

2. Small amplitude surface waves
Different wave regimes - General formulation, linearisation of the boundary conditions, the dispersion relationship, fluid particle kinematics - Energy, reflection, shoaling, refraction, diffraction - wave current interaction - mass transport, momentum flux

### Learning outcomes

- Students should be able to calculate the properties of a wave as a function of period, depth and wave height.
- Students should be able to calculate the variation in wave properties as the wave approaches the coast.
- Students should be able to calculate the wave and current-induced forces on a simple structure.
- Students should be able to estimate the threshold of movement for sediments exposed to the action of waves and currents.

### Independent study

Objectifs :

Méhodes :

### Core texts

DEAN, R.G. & DALRYMPLE, R.A., *WATER WAVE MECHANICS FOR ENGINEERS AND SCIENTISTS*, Prentice-Hall
PEDLOSKY, J. *GEOPHYSICAL FLUID DYNAMICS.*, Springer Verlag
SLEATH, J.F.A.*SEA BED MECHANICS*, Wiley

### Assessment

Written exam (2h): 40%; Lab reports and design exercises (3): 60%

## *GREEN COMPUTING*

## GREEN COMPUTING

**Lecturers:** Ian O CONNOR, Alberto BOSIO

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : FR

### Objectives

This course aims to study the execution of applications on computing architectures from the points of view of functionality, performance and energy efficiency. In this context, parallel hardware architectures (multi-core processors, SIMD machines and GPUs), hardware communications resources (bus and network) as well as the efficient deployment of applications on these hardware resources will be discussed: task placement, hardware / software partitioning and matching algorithm requirements to architecture resources. Techniques for estimating energy consumption will be presented and will make it possible to estimate the cost of memory access, calculations and communications.

Keywords : Energy consumption in digital electronic systems, Low power design techniques, Parallel computing architectures, Application deployment, matching algorithm requirements to architecture resources

### Programme

Principles of hardware/software partitioning and processor sizing Multi-core architectures and programming
Strategies for deploying tasks and reducing consumption
Energy cost of inter-core communication or distributed computing
Multi-level abstraction energy estimation of software execution

Personal work and study class: analysis of energy-efficient supercomputers (green500.org)
Practical work (2 4-hour sessions): programming an image filter on an embedded GPU,

### Learning outcomes

- Understand the issues and origins of energy consumption in computing architectures
- Be able to evaluate energy consumption in processors
- Be able to optimize the programming of algorithms on processors to minimize energy consumption

### Independent study

Objectifs : Analysis of energy-efficient supercomputers (green500.org)

Méhodes : Analysis (in groups of 2) of a supercomputer chosen from the green500.org list, comparison with supercomputers from the top500.org list, written report and oral defense

### Core texts

### Assessment

2 hour written test without documents (50%)
Personal work and study class (25%)
Practical work (25%)

## *HYDRAULIQUE FLUVIALE*

## RIVER HYDRAULICS

**Lecturers:** Richard PERKINS

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : AN

### Objectives

For centuries rivers have been exploited in many ways (e.g. to provide water for domestic or irrigation purposes, for transportation, for power generation) but even today, major river floods can have devastating consequences. The aim of this course is to provide students with a comprehensive understanding of the fundamental processes in hydraulic engineering, through the development of suitable yet simple models.

Keywords : Rivers, Hydraulics, Free-surface flows, Specific energy, Specific force, Hydraulic jump, Surge waves, Sediment transport

### Programme

1. Introduction
Hydrological cycle - the river system - current issues in river engineering.

2. Uniform flow in open channels
Wave speed - Critical depth - flow regimes - Specific energy - Specific force - Hydraulic jump.

3. Gradually-varied flow
Flow resistance - Uniform flow and the normal depth - surface profiles

### Learning outcomes

- Students should be able to calculate the surface profile for steady flow through a change in channel section.
- Students should be able to calculate the surface profile of a steady flow in an inclined channel, as a function of channel slope, channel roughness, flow rate and inlet or outlet conditions.
- Students should be able to calculate the propagation of a wave in an open channel.
- Students should be able to calculate the threshold of movement for given sediment properties.

### Independent study

Objectifs :

Méhodes :

### Core texts

HENDERSON, F. , *OPEN CHANNEL FLOW* , Macmillan
RAUDKIVI, A.J. *LOOSE BOUNDARY HYDRAULICS* , Balkema
VIOLLET, P.-L. et al *MÉCANIQUE DES FLUIDES APPLIQUÉE* , Presses de l'ENPC

### Assessment

Written exam (2h): 40%; Lab reports and design exercises (3): 60%

## *IDENTIFICATION DES SYSTÈMES ET DÉCOMPOSITION PARCIMONIEUSE DES SIGNAUX*

## SYSTEM IDENTIFICATION AND SPARSE DECOMPOSITIONS

**Lecturers:** Julien HUILLERY, Laurent BAKO, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

The understanding of physical phenomena coupled with the advancement of observation technologies, the needs of analysis, diagnosis and control of engineering systems make more and more use of experimental modeling. This modeling work is a prerequisite for the synthesis of control laws of dynamic systems or the analysis and processing of signals. The goal of this course is to provide advanced principles and methods of signal and system modeling. "System identification" aims to associate a mathematical model with a dynamic system on the basis of noisy data measured with sensors. The "sparse decomposition of signals" aims at a compact modeling of a signal via its decomposition in a dictionary.

Keywords : experimental modeling, system identification, parametric estimation, sparsity, dictionary of signals, time-frequency representations, compressed sensing, optimization

### Programme

Part I: Systems Identification
Introduction to Signal and System Modeling: System Point of View
Concept of model structure: definition and examples
Estimation methods based on the minimization of the prediction error
Elements for the analysis: identifiability, persistence of excitation, frequency richness of a signal
Asymptotic properties of the estimators: consistency, convergence in distribution

Part II: Sparse Decomposition of Signals

### Learning outcomes

- To understand the application issues of signals and systems modeling
- To construct and identify a model of system from experimental measurements
- To know the usual bases of representation of signals
- To determine a sparse representation of a signal

### Independent study

Objectifs :

Méhodes : The lectures are completed with 3 practical works under Matlab / Simulink:
BE 1: Implementation of identification methods on an example
BE 2: Sparse decomposition of signals
BE 3: Compressed Sensing

### Core texts

L. Ljung, *SYSTEM IDENTIFICATION: THEORY FOR THE USER*, PTR Prentice Hall, 1999
S. Mallat *A WAVELET TOUR OF SIGNAL PROCESSING, THE SPARSE WAY*, Academic Press, 2009
S. Boyd and L. Vandenberghe*CONVEX OPTIMIZATION*, Cambridge University Press, 2004

### Assessment

Final mark = 50% knowledge + 50% know-how
Knowledge = 100% final exam
Know-how = 100% continuous assessment

## *INFORMATION QUANTIQUE*

## PHYSICS FOR INFORMATION TECHNOLOGY

**Lecturers:** Anne-Segolene CALLARD

| Lecturers : 16.0 | TC : 0.0 | PW : 4 | Autonomy : 0.0 | Study : 8 | Project : 0.0 | Language : FR

### Objectives

Over the past two decades, the rapid evolution of quantum systems engineering has paved the way to new forms of processing and transmission of information. At the crossroads of quantum mechanics, computer science, information theory and engineering, the development of quantum computers allows to consider solutions to problems that seemed impossible to solve with a classical approach. The objective of the course aims at understanding the challenges linked to the developments of quantum information and at perceiving in what extent they can modify the current landscape of information processing.

Keywords : Qubit, superposition, entanglement, quantum cryptography, teleportation, quantum computer, photons, superconducting junctions.

### Programme

1. Introduction, complexity of an algorithm, class of a problem, promises of quantum information, limits. Quantum superiority. What can we solve with a quantum calculator?
2. Quantum mechanics, postulates, notion of Qubit, Cryptography
3 Two-Qubit system, intricacies-correlations, EPR paradox
4. Teleportation, indistinguishability, decoherence, limits.
5. Calculations: quantum gates
6. Quantum algorithms
7. Physical implementations: the qubit photon
8. The superconducting qubit, today's quantum computer today

### Learning outcomes

- Explain the concept of quantum superiority and identify the advantages of quantum computing, its limits
- Describe the main platforms envisaged to implement qubits,
- Explain the principles of the main quantum algorithms and their interests.
- Describe the evolution of a qubits system through a quantum logic gate.

### Independent study

Objectifs : 1TP Single photon sources
1 BE quantum calculations (IBM simulators)
1 BE A bibliographic research work of your choice with oral restitution in pairs.

Méhodes : bibliographic research work of your choice with oral restitution in pairs.

### Core texts

M. A. NIELSEN and I. L. CHUANG, *QUANTUM COMPUTATION AND QUANTUM INFORMATION*, Cambridge University Press, 2016
Pascal Degiovanni, Natacha Portier, Clément Cabart, Alexandre Feller et Benjamin Roussel *PHYSIQUE QUANTIQUE, INFORMATION ET CALCUL*, EDP Sciences - Collection : Savoirs Actuels, 2020

### Assessment

Score = 50% knowledge + 50% know-how
Knowledge score = final exam
Know-how score = 40% TP mark + 60% BE mark (oral presentation).

## *INGÉNIERIE D'UN OBJET DE GRANDE CONSOMMATION*

## ENGINEERING OF A CONSUMER OBJECT

**Lecturers:** José PENUELAS

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

The main objective of this course is to show to the students who have not previously followed scientific studies the implication and entanglement of engineering sciences and techniques from a given object. This module is an opportunity to introduce the multidisciplinary approach specific to the general engineer by exposing the concepts and tools of physics, materials science, signal processing, automation that exist in the design and the realization of consummer goods such as the optical disc.

Keywords : Engineering, Matérials, Physics, Signal processing, Automation, Design

### Programme

- Introduction
- Physics
- Material science
- Design
- Signal processing
- Automation

### Learning outcomes

- Understand the multi-disciplinary nature of the design of everyday objects.
- Possess some fundamentals in the disciplines involved.

### Independent study

Objectifs :

Méhodes :

### Core texts

### Assessment

Final graduation will take into account the practicals session (know_how = 1/3) and the final exam (knowledge = 2/3).

## *INTERACTIONS FLUIDE-STRUCTURE*

## FLUID-STRUCTURE INTERACTIONS

**Lecturers:** Mohammed ICHCHOU, Gilles ROBERT, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : MI

### Objectives

Introduction of the fluide Structure Interactions (FSI) problems. Modeling of such coupling situations and design of mechanical systems evolving fluide Structure Interactions.

Keywords : Added mass operator - elastic effects - Sloshing - Free surface effects - Gravity waves - Capilarity waves -Fluide-structure impacts - Dissipative effects - Radiation - COupled fluid-structures modes - FInite Element modeling - Piston like cases - Instabilities - Forcing through the fluid - incompressible effects - compressible effects.

### Programme

I- Classification of the main fluide-structure problems.
II- FOrmulation of the fluid-structure coupling issues.
III- INertia effects and strong coupling.
IV- Dissipative coupling - radiation effects
V- Vibroacoustic coupling (boiunded and unbounded)
VI- Physical interpretation of the fluid-structure coupling effects, numerical formulation and assessments.
VII- Fluid-structure coupling under flow

### Learning outcomes

- Assessment of the type of fluide structure interaction
- Assessment of the relevant parameters belonging to the main fluid-structure interactions
- Being able to formulate the relevant model for the main fluid-structure interaction
- Define the relevant sources of excitations by the fluid injected in the structure

### Independent study

Objectifs : Analysis of a real case and assessments of its class among the possible fluid-structure families

Méhodes : Analysis of a journal paper/patent

### Core texts

F. Axisa, *MODÉLISATION DES SYSTÈMES MÉCANIQUES VOL. 3 : INTERACTIONS FLUIDE STRUCTURE*, Lavoisier
Emmanuel de Langre *FLUIDES ET SOLIDES*, Ecole Polytechnique, 2002
J. P. Morand et R. Ohayon*INTERACTIONS FLUIDES-STRUCTURES*, Broché, 1997

### Assessment

Reports of the Experimental/numerical trainings (team work)
Report on a chosen journal paper/patent (team work)
Final individual exam

*INTRODUCTION À DATA SCIENCE*

## MACHINE LEARNING AND DATA MINING

**Lecturers:** Alexandre SAIDI, Céline HARTWEG-HELBERT, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

Keywords :

### Programme

### Learning outcomes

### Independent study

Objectifs :

Méhodes :

### Core texts

u.m. Fayyad & al. From Data Mining to Knowledge Discovery in Databases. 1996.
stan matWin & al. Challenges in Computational Statistics and Data Mining. Jan Mielniczuk, 2016.
i.h. Witten, e. Frank. Data Mining - practical ML Tools & Techniques. 2005.

### Assessment

## *INTRODUCTION AUX VIBRATIONS NON-LINÉAIRES*

## INTRODUCTION TO NONLINEAR VIBRATIONS

**Lecturers:** Joël PERRET LIAUDET, Fabrice THOUVEREZ, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : FR

### Objectives

This course is an introduction to the main phenomena related to the problems of nonlinear vibrations. The minimum knowledge and rules useful to the engineer will be introduced to diagnose and treat these problems. Many examples from engineering problems will illustrate the course. We can mention the dynamics of frictional contacts (squeal noise), clearance systems (rattling), rotors dynamics and gear transmissions, bridges subjected to wind .

Keywords : nonlinear vibrations, dynamics of systems, stability, bifurcations, nonlinear modes, principal resonances, super-harmonics, sub-harmonics, self-sustained vibrations, galloping, flutter phenome

### Programme

* Generalities on nonlinear vibratory problems in engineering, classification of sources
* Description and Analysis Tools, Nonlinear Modal Analysis
* Loss of equilibrium stability and self-sustained vibrations (galloping phenomena, squealing)
* Phenomena of nonlinear resonances (principal and harmonics)
* Concept of strange responses (chaos)
* Introduction to methods specific to the treatment of nonlinear phenomen

### Learning outcomes

- detect and / or diagnose nonlinear vibration phenomena
- characterize the main kinds of vibration responses
- identify the main phenomena that lead to these dynamic responses
- model some nonlinear problems and use specific methods

### Independent study

Objectifs : Study of vibro impacting systems and hertzian contacts under normal excitations.
Study of friction instabilities.
Practical methods devoted to nonlinear problems
knowledge of several scenarii inducing chaos.

Méhodes : Practical works, Design project

### Core texts

A. H. Nayfeh, B. Balachandran. , *APPLIED NONLINEAR DYNAMICS: ANALYTICAL, COMPUTATIONAL AND EXPERIMENTAL METHODS*, J. Wiley, 1995
Vidal, Bergé, Pommeau *L'ORDRE DANS LE CHAOS*, Hermann, 1984
Manneville, P.*INSTABILITÉS, CHAOS ET TURBULENCE*, Ecole Polytechnique, 2004

### Assessment

final = 50% knowledge + 50% know how
knowledge = 100% final exam
know how = 100% continuous monitoring

## *LE SYSTÈME ÉLECTRIQUE*

## ELECTRIC POWER SYSTEM

**Lecturers:** Eric VAGNON

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12 | Project : 0.0 | Language : FR

### Objectives

The electrical system is a major infrastructure of modern societies. The liberalization of the sector in recent years has profoundly changed its management in a large number of countries and particularly in Europe.
The objective of the course is to give the technical basis for understanding the functioning of the electrical system and to present the organization of the system through the role and relationships between the different actors: producers, transmission system operators, balance responsible and consumers.

Keywords : Generation, transmission, grid operator, balance of production and consumption, short and long term planning

### Programme

The electrical system in the energy context
Generation/consumption balance
Voltage plan
The different actors of the electrical system, their roles and relationships in the context of market liberalization
The planning of the network
Analysis of major incidents
Functioning of the electrical energy market

### Learning outcomes

- Name the technical or economic constraints and advantages of an extended electrical system
- Differentiate the role of the different players in the electrical system
- Define actions to manage the electrical system
- Interpret and explain changes observed on a network

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

P. Bastard et al., *ELECTRICITÉ, VOYAGE AU COEUR DU SYTÈME.*, Eyrolles, 1999

### Assessment

Final mark = 70% Knowledge + 30% Know-how

## *LES TURBINES POUR LA PRODUCTION D'ÉNERGIE*

## POWER PLANT TURBINE TECHNOLOGY

**Lecturers:** Pierre DUQUESNE, Alexis GIAUQUE

| Lecturers : 16.0 | TC : 4.0 | PW : 4.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : FR

### Objectives

In this course, we pay attention to the different turbomachinery, alone or in association, used for energy production right now or in the near future. The available resources are analysed and are discussed dependent on the type, on the geometry and on the main dimensions of the different turbomachinery and their operating modes.A part of the electricity produced with turbomachinery came from direct extraction of the energies of the wind (wind turbines), from the rivers or from the water head (hydraulic turbines). The last part of the production came from an association of different turbomachinery (compressor, turbine and heat source), often called gas turbines or steam turbines. These systems producing both heat and mechanical power

Keywords : Energy production, hydraulic turbines, wind turbines, gas turbines, steam turbines

### Programme

- Hydraulic turbines: geometries (impulse and reaction turbine, Francis, Kaplan, Pelton), energy transfer (Euler equation), efficiency, similitude law, cavitation phenomena.
- Wind turbines: geometries, size, blade numbers, power recoverable (Betz law), regulation.
- Gas turbine: introduction to energy production from a heat source, energy exchange in the different component (concepts of shaft work and stagnation variables), transformations graphical representation, components description.
- Steam turbines: Rankine's cycle, Hirn's cycle and improvement (reheat, extraction)

### Learning outcomes

- Understand the energy production with turbomachinery
- Know how to design a hydraulic turbine
- Know how to design a wind turbine
- Know how to calculate the cycle of steam or gas turbine

### Independent study

Objectifs : Explain the operation of a Pelton turbine, Gaz turbine or Wind turbine analysis from the laboratory.

Méhodes :

### Core texts

### Assessment

Final mark = 60% Knowledge + 40% Know-how
Knowledge = 100% final exam
Know-how = 100% continuous assessment ,

## *MATÉRIAUX DE CONSTRUCTION*

## CONSTRUCTION MATERIALS

**Lecturers:** Eric VINCENS

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : FR

### Objectives

It is a revolution which is being prepared in the building sector: that of the necessary use of more frugal construction techniques, that is to say more economical in embodied energy, less impacting for the environment and a less drain on the buildings. natural resources thanks to the ability of materials to be recycled or better reused.

Thus, alongside conventional techniques, such as steel construction or reinforced concrete, more confidential techniques such as wood or straw construction and vernacular techniques neglected in the 20th century, such

Keywords : aggregates, binders, concrete, steel, wood, earth, dry stone

### Programme

We will successively address conventional materials such as aggregates, binders such as cements, plaster, lime, concretes (current, high or very high performance, fibers, self-placing, low carbon), steel or wood for construction. and unconventional construction materials or techniques such as straw-bale, earthen and dry stone.

The use of conventional materials will be placed in its industrial and normative context, emphasis will be placed on the action of the environment which tends to alter or modify their properties, both physically and mechanically.

### Learning outcomes

- know how to identify and characterize materials for construction
- know the problems of durability of the materials in their environment

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

G. Dreux, *NOUVEAU GUIDE DU BÉTON ET DE SES CONSTITUANTS*, Eyrolles, , 1998
Acovitsioti-Hameau, Ada; Cagin, Louis *PIERRE SÈCHE : THÉORIE ET PRATIQUE D'UN SYSTÈME TRADITIONNEL DE CONSTRUCTION* , Eyrolles, 2017
Ulrich Röhlen, Christof Ziegert, Catherine LattucaId *CONSTRUIRE EN TERRE CRUECONSTRUCTION, RÉNOVATION, FINITIONS* , Le Moniteur Editions, 2013

### Assessment

- Microtests: closed-book examination
- Final exam: closed-book examination
Grade : 2/3 final exam + 1/3 activities (microtests+lab)

# *MATIÈRE MOLLE : NANOSYSTÈMES ET INTERFACES BIOLOGIQUES*

## SOFT MATTER

**Lecturers:** Denis MAZUYER

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : MI

### Objectives

Many complex molecular systems (synthetic or natural) are used, in low concentration, to control functions such as detergency, coating capability, anti-icing, therapeutic targeting, ... by giving a very strong response to a very weak control signal (electrical, mechanical, thermal). These technologies are based upon of a strong state of division of matter giving large interfaces between immiscible liquids or between solid and liquids. The aim of the course is to present the fundamental processes governing the dynamics state of matter called "colloidal" state and to understand the physicochemical and rheological properties of common objects (lubricants, drugs, food, cosmetics, paints, cells. ) in variable applications ranging from biotechnology to civil engineering.

Keywords : Wetting, adhesion, rheology, colloids, biotechnology, physco-chemistry of interfaces, solution of polymers, self-assembly

### Programme

I. The colloidal state: Definition, classification, main properties and characterization methods, Self-assembled molecular systems
II. Colloidal physico-chemistry: Dispersions, emulsions and biomedical aspects, Colloids for diagnosis and in biotechnology, wetting and intermolecular forces
III. Solutions of polymers: Chain conformations and role of the solvent, Polymer at interfaces for colloidal stability
IV. Flow properties of soft matter: Introduction to rheology - models and experimental methods, Rheology of diluted and concentrated suspensions and role of colloidal interactions

### Learning outcomes

- To estimate the influence of the structure of soft materials on their properties and to modify surfaces to impart a desired functionality to them
- To obtain a theoretical understanding of the physics of soft condensed matter
- To design microscopic materials made from colloidal buildling blocks, stable emulsions and dispersions
- To obtain an insight of some experimental techniques that are relevant for investigating soft material physics.

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

P.-G. de Gennes,, *SCALING CONCEPTS IN POLYMER PHYSICS*, Cornell University Press, 1979
P. Coussot, J.-L. Grossiord *COMPRENDRE LA RHÉOLOGIE*, EDP Sciences, 2002
P. Coussot, C. Ancey*RHÉOPHYSIQUE DES PÂTES ET DES SUSPENSIONS*, EDP Sciences, 1999

### Assessment

Final mark = 2/3 Knowledge + 1/3 Know-how

Knowledge = 50% final exam + 50% continuous assessment

## *MÉTHODES NUMÉRIQUES POUR LES EDP*

## NUMERICAL METHODS FOR PDES

**Lecturers:** Grégory VIAL, Alexandre SAIDI, Céline HARTWEG-HELBERT, Hélène

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

We will present the most common methods to approximate solutions to partial differential equations. Rather than giving an exhaustive list of the most efficient methods used in industrial codes, we will describe the mathematical foundations for the setting and the analysis of the principal methods. Some of them will be implemented with Matlab.

Keywords : Numerical methods. Scientific computing. Partial differential equations.

### Programme

Chapter 1. Basics on the theory of linear PDEs, and finite difference methods.
Chapter 2. Finite element methods for elliptic problems
Chapter 3. Numerical approximation for scalar conservation laws

### Learning outcomes

- To identify the nature of a PDE and the main difficulties for its numerical approximation
- To learn the main categories of numerical methods
- To identify the behavior of the methods and their limitations
- To be able to implement the main methods for simple problems

### Independent study

Objectifs : Implementation of numerical methods on simple but typical examples

Méhodes :

### Core texts

A. Ern, J.-L. Guermond, *ELEMENTS FINIS : THEORIE, APPLICATIONS, MISE EN ŒUVRE. MATHEMATIQUES ET APPLICATIONS*, Springer, 2002
B. Despres, F. Dubois *SYSTEMES HYPERBOLIQUES DE LOIS DE CONSERVATION : APPLICATION A LA DYNAMIQUE DES GAZ.*, Ecole Polytechnique, 2005

### Assessment

Evaluation = 60% knowledge + 40% know-how
Knowledge = 100% final exam
Know-how = 100% continuous assessment

## *MÉTHODES VARIATIONNELLES POUR LES EDP*

## VARIATIONAL METHODS FOR PDES

**Lecturers:** Martine MARION

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

Variational methods, also called energy methods, are a major tool in the study of partial differential equations (PDEs) for linear and nonlinear problems. They rely on estimates of the solutions in well chosen functional spaces and the use of powerful methods borrowed from the theory of functional analysis.
The aim of this course is twofold :
- to study the tools in analysis underlying these methods
- to apply them to the study of stationary PDEs (elliptic problems) as well as unsteady problems (parabolic problems).

Keywords : Partial differential equations, weak solutions, linear and non linear problems, variational methods

### Programme

Chapter 1 : Sobolev spaces
- Introduction to the theory of distributions
- Density and trace theorems

Chapter 2 : Linear elliptic problems
- Variational methods
- Eigenvalue problems

Chapter 3 : Nonlinear elliptic problems
- Weak topology
- Galerkin method

### Learning outcomes

• To learn the analysis tools at the basis of the study of PDEs To be able to apply them to actual problems

### Independent study

Objectifs :

Méhodes :

### Core texts

H. Brézis, *ANALYSE FONCTIONNELLE*, Dunod, 2005
R. Dautray et J.L. Lions *ANALYSE MATHÉMATIQUE ET CALCUL NUMÉRIQUE*, Dunod, 1988
R. Temam*THEORY AND NUMERICAL ANALYSIS OF THE NAVIER-STOKES EQUATIONS*, North Holland, 1979

### Assessment

Final mark = 70% Knowledge + 30% Know-how
Knowledge N1 = 100% final exam
Know-how N2 = 100% continuous assessment

## *MÉCANIQUE DES MATÉRIAUX ET STRUCTURES COMPOSITES*

## MECHANICS OF COMPOSITE MATERIALS AND STRUCTURES

**Lecturers:** Mohammed ICHCHOU, Marc JACOB, Olivier BAREILLE

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : AN

### Objectives

Keywords : anisotropy
laminated composites
sandwich structures
homogeneization

### Programme

Composite structures and materials
Structural models
3D models
Laminated plates' theory
Homogenization
Dynamic behavior
Damages

### Learning outcomes

- knowing the types of composites knowing the models homogenization theory mechanism of damage

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

Carl T. Herakovich, *MECHANICS OF FIBROUS COMPOSITES*, John Wiley & Sons, 2004
J.N. Reddy *MECHANICS OF LAMINATED COMPOSITE PLATES*, CRC Press, 1997
D. Gay, S. V. Hoa, S. W. Tsai *COMPOSITE MATERIALS: DESIGN AND APPLICATIONS*, CRC Press, 2003

### Assessment

## *MICROSYSTÈMES AUTONOMES*

## AUTONOMOUS MICROSYSTEMS

**Lecturers:** Ian O CONNOR, Pedro ROJO ROMEO

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : FR

### Objectives

Spectacular advances in the field of micro-nano-technologies have paved the way for the integration of extremely diverse functionalities in a volume of the order of mm3. Autonomous microsystems, based on this integration and at the heart of the emergence of sensor networks and the Internet of Things, do not require an external energy supply, are able to communicate wirelessly and integrate sensors/actuators as well as data processing circuits. Their applications are numerous: distributed sensor/actuator systems in automotive, civil engineering, health, production lines, etc.

Keywords : micronanoelectronic technologies, sensors/actuators, energy harvesting, low power design

### Programme

Introduction to the principles of microelectronic technologies
Description of specific integrated sensor/actuator technologies, applications
Ambient energy harvesting
Electronic signal conditioning
Constraints linked to nanoscale integration (thermal, mechanical, noise, etc.)

Practical work: Introduction to micro-nanotechnologies in a clean room
Practical work: Design of a low-noise, low-power, low-voltage CMOS amplification block
Study class: study of an autonomous microsystem

### Learning outcomes

- Understand the issues and principles of autonomous microsystems
- Know the manufacturing techniques and operating principles of integrated microsensors
- Be able to analyze an integrated circuit handling sensor signal conditioning and acquisition
- Know energy recovery techniques (mechanical, thermal, photovoltaic) at the integrated scale

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

S. Senturia, *MICROSYSTEM DESIGN*, Springer, 2000
N. Maluf *AN INTRODUCTION TO MICROELECTROMECHANICAL SYSTEMS ENGINEERING*, Artech, 2004

### Assessment

2-hour written test without documents (50%)
Practical work (lab work, study class) (50%)

## *MOD PARCOURS ENTREPRENEUR 1*

## ENTREPRENEURIAL COACHING 1

**Lecturers:** **Thierry FARGERE, Sylvie MIRA**

| Lecturers : 8.0 | TC : 20.0 | PW : 0.0 | Autonomy : 0.0 | Study : 0.0 | Project : 0.0 | Language : FR

### Objectives

The course provides a coaching for entrepreneur students in the development of their project as well as competencies in law, finance, negociation, entrepreneur pitch

Keywords : Entrepreneurship, business model, lean start up

### Programme

Business creation: content and process
Market analysis : customers, competitors, value chain and change drivers
Business model: revenu model and resources organisation
Communication and negociation

### Learning outcomes

- Entrepreneurial project management
- Market analysis and market entry
- Value proposition design
- Communicate on the project: business plan and pitch

### Independent study

Objectifs : Work on project, interviews, prototyping

Méhodes :

### Core texts

Osterwalder A., Pigneur Y, *BUSINESS MODEL GENERATION: A HANDBOOK FOR VISIONARIES, GAME CHANGERS, AND CHALLENGERS*, Willey, 2010
Ries E *THE LEAN STARTUP: HOW CONSTANT INNOVATION CREATES RADICALLY SUCCESSFUL BUSINESSES*, Penguin, 2011
Masterson AK*BUSINESS MODEL GENERATION: THE BLUEPRINTS EVERY ENTREPRENEUR IN EVERY INDUSTRY NEEDS TODAY TO ACHIEVE MAXIMUM PROFITS*, CreateSpace

### Assessment

Business plan and pitch

## *MOD PARCOURS ENTREPRENEUR 2*

## ENTREPRENEURIAL COACHING 2

**Lecturers:** **Thierry FARGERE, Alexandre SAIDI, Sylvie MIRA**

| Lecturers : 8.0 | TC : 20.0 | PW : 0.0 | Autonomy : 0.0 | Study : 0.0 | Project : 0.0 | Language : FR

### Objectives

The course provides a coaching for entrepreneur students in their business creation process as well as competencies in law, finance, negociation, entrepreneur pitch

Keywords : Entrepreneurship, business model, lean start up

### Programme

Business creation: content and process
Market analysis : customers, competitors, value chain and change drivers
Business model: revenu model and resources organisation
Communication and negociation

### Learning outcomes

- Startup creation management
- Market analysis and market entry
- Value proposition design
- Communicate on the project: business plan and pitch

### Independent study

Objectifs : Work on project, interviews, prototyping

Méhodes :

### Core texts

Osterwalder A., Pigneur Y, *BUSINESS MODEL GENERATION: A HANDBOOK FOR VISIONARIES, GAME CHANGERS, AND CHALLENGERS*, Willey, 2010
Ries E *THE LEAN STARTUP: HOW CONSTANT INNOVATION CREATES RADICALLY SUCCESSFUL BUSINESSES*, Penguin, 2011
Masterson AK*BUSINESS MODEL GENERATION: THE BLUEPRINTS EVERY ENTREPRENEUR IN EVERY INDUSTRY NEEDS TODAY TO ACHIEVE MAXIMUM PROFITS*, CreateSpace

### Assessment

Business plan and pitch

## *MOD PARCOURS INTRAPRENEUR 1*

## BUSINESS DEVELOPMENT 1

**Lecturers:** **Marie GOYON**

| Lecturers : 0.0 | TC : 28.0 | PW : 0.0 | Autonomy : 0.0 | Study : 0.0 | Project : 0.0 | Language : FR

### Objectives

Train pilots of innovative projects in companies, able to meet the challenges of tomorrow, systemic changes, whether in the environment, the economy, the social… Innovations that can address these cross-cutting issues cannot focus on a one-discipline approach.
The approach focuses on the project: learning by doing, DIY and DIWO: students work in project groups on topics proposed by companies. Approach to open innovation, its different configurations and ecosystems. Deepening of the methods and postures seen in IIE.

Keywords : intrapreneurship, innovation, piloting project

### Programme

Training by the project, in teams, from a «brief», subject given by the company. Course modules, coaching and application on project. Internal collaboration with company project team (appointment, meetings, visits...).
Course: deepening Profession IIE. (Design thinking, Buisness models, Field surveys, actor networks...). Complementary contributions in Open innovation (testimonials, case studies). Prototyping, fablab.

### Learning outcomes

- Know how to evaluate the desirability, feasibility and viability of a concept and solution. Iteration, testing, prototyping.
- Know how to lead a team, work in an interdisciplinary context, manage an innovative project. Dialogue, agility, médiation, management.
- Know how to lead a team, work in an interdisciplinary context, manage an innovative project. Dialogue, agility, médiation, management.

### Independent study

Objectifs : Project : planning, workshops, piloting etc

Méhodes : Project

### Core texts

### Assessment

Report and oral evaluations

## *MOD PARCOURS INTRAPRENEUR 2*

## BUSINESS DEVELOPMENT 2

**Lecturers:** Marie GOYON

| Lecturers : 0.0 | TC : 28.0 | PW : 0.0 | Autonomy : 0.0 | Study : 0.0 | Project : 0.0 | Language : FR

### Objectives

Training in the management of innovative projects in companies.
A global approach, courses, coaching and autonomy: Observe the internal and external uses and challenges of an innovation, develop an idea, confront it to reality, choose a technology, compose an offer, define a business model, recommend processes, setting up a project, identifying resources, federating a network of stakeholders, ensuring reporting, etc.

Keywords : intrapreneurship, innovation, piloting, communication, project, agility

### Programme

Students work on real projects with project leaders, collaborating with internal teams. Company sequences and field surveys.
Courses and coaching.
Courses: deepening of the IIE Metier and Open Innovation contributions (testimonials and case studies), in-depth investigations and prototyping (fablab)

### Learning outcomes

- Know how to lead a team, work in an interdisciplinary context, manage an innovative project. Dialogue, agility, médiation, management.
- Know how to evaluate the desirability, feasibility and viability of a concept and solution. Iteration, testing, prototyping.
- Know how to design disrupting products, services or systems embedded in social and economical reality. Research, conception, analysis, intuition and creativity

### Independent study

Objectifs : Piloting project, team, communication, reporting, planning

Méhodes : Project

### Core texts

### Assessment

Report and oral evaluations

## *NANOPHOTONIQUE*

## NANOPHOTONICS

**Lecturers:** Emmanuel DROUARD, Christelle MONAT

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : MI

### Objectives

Significant advances have been achieved in Photonics, for light emission, processing, transport and detection, with implications in a wide range of application areas. Progress related to fabrication, which leverage the microelectronics infrastructure and expertise regarding the realization of micrometer scale devices, has enabled the implementation of new concepts of integrated optics for the control of light, which are now commonly used. Current research is very active in the field of sub-micrometer devices, such as photonic crystals, and will benefit to key application areas: information and communications, biology, energy. The aim of this course is to give the physics background underpinning these new technologies, for understanding a more specialized literature.

Keywords : Birefringence, Optical Waveguide, Photonic Crystal, Non-Linear Optics

### Programme

Polarization of the light
Planar guided optics
Integrated Optics & Fiber Optics
Photonic crystals and nanophotonics: basics and possible applications
Nonlinear optics: Kerr effect, frequency doubling, wavelength conversion.
2 Lab works: Finite Difference Time Domain » simulation of integrated optics devices, Transmission of a signal using electro optic modulation
1 tutorial: Non linear Optics for wavelength conversion

### Learning outcomes

- to be able to describe the light propagation in a birefringent material
- to understand and to use the effects of the index profile and the wavelength on optical guided modes
- to understand and to be able to use the dispersion properties of micro-nanophotonics structures
- to understand the origin of the nonlinear optics phenomena and how they can be applied to all-optical signal processing

### Independent study

Objectifs :

Méhodes :

### Core texts

B.E. A . Saleh, M. C Teich, *FUNDAMENTAL OF PHOTONICS*, Wiley, 2007
H. Rigneault, J.M. Lourtioz *LA NANOPHOTONIQUE*, Lavoisier, 2005

### Assessment

70% knowledge (final exam), 30% knowhow (Labs/tutorial)

## *NANOTECHNOLOGIES*

## NANOTECHNOLOGIES

**Lecturers:** Magali PHANER GOUTORBE, Emmanuelle LAURENCEAU

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : FR

### Objectives

Nanosciences and nanotechnologies deal with the understanding of the specific properties of structures at the nanoscale, as well as the development and characterization of these nanostructures. Nanotechnologies make it possible to push back the limits of miniaturization and generate new applications and new functionalities in microelectronics, photonics, materials science, biology with applications in medicine, energy and environmental issue.
This course presents the specific properties of nanostructures and nanomaterials, as well as the observation and development tools at the nanometric scale.

Keywords : Physics of low dimensional systems, Electron and Near field Microscopies, Nanolithography, Nanomaterials, Nanoelectronics and Nanophotonics, Nanobiotechnologies, Nanotechnology for energy and for the environmental issues.

### Programme

Introduction to nanosciences and nanotechnologies.
Applications of nanotechnologies in everyday and tomorrow's objects (smartphone, nanorobot, medical nanocapsule, for energy and the environment ...)
Techniques of observation and characterization of nanostructures.
Nanolithography manufacturing processes.
Nanomaterials, nanowires and nanoparticles.
Nanoelectronics, molecular electronics, single electron transistor.
Nanophotonics.
Nanobiotechnologies: DNA and protein biochips, molecular self-assembly and biology,

### Learning outcomes

- Understand the challenges of nanotechnologies in the fields of information technology, materials, medicine, energy and the environment. Understand the physical phenomena of low dimensional structures. Reflect on future developments in Nano.
- Deepen the understanding of a technique for developing nanostructures by participating in the fabrication of a typical sample. Deepen the understanding of a technique for characterizing nanostructures by participating in the observation at the nanometric scale of this same sample
- Explain through the creation of an educational video the specific contribution of

### Independent study

Objectifs : Deepen the knowledge of the course
Acquire knowledge on a field of nanotechnologies little or not covered in class
Work in groups (4-5 students)

Méhodes : Review the concepts covered in class
Create educational videos on a field of application little covered in class from scientific articles and with the help of the pedagogy department

### Core texts

M. LAHMANI , C. BRECHIGNAC, P. HOUDY ., *LES NANOSCIENCES. TOME 1: NANOTECHNOLOGIES ET NANOPHYSIQUE. EDITIONS BELIN, 2004.*, Editions Belin, 2004
M. LAHMANI , C. BRECHIGNAC, P. HOUDY . *LES NANOSCIENCES. TOME 2: NANOMATÉRIAUX ET NANOCHIMIE.*, Editions Belin, 2006
M. LAHMANI , C. BRECHIGNAC, P. HOUDY .*LES NANOSCIENCES. TOME 3: NANOBIOTECHNOLOGIES ET NANOBIOLOGIE.*, Editions Belin, 2007

### Assessment

Assessment of practical activity TP.
Evaluation of the Video Project activity.
Written final test

## *OCÉANOGRAPHIE : CONCEPTS GÉNÉRAUX ET ÉTUDES DE CASS*

## OCEANOGRAPHY : GENERAL CONCEPTS AND CASE STUDIES

**Lecturers:** Louis GOSTIAUX, Pietro SALIZZONI

| Lecturers : 16 | TC : 0 | PW : 0.0 | Autonomy : 0.0 | Study : 12 | Project : 0.0 | Language : AN

### Objectives

This course will address several aspects in the field of Ocean Sciences, in relation with the scientific background of students in mathematics (signal processing, numerical modelling), physics & chemistry (fluid mechanics, thermodynamics) and energetics (energy balance, geo-engineering). Ocean Sciences cover an important field of knowledge related to environmental, economcal and geopolitical questions of the XXIst century. Several applied studies will be made by the students in order to introduce them to realistic datasets and cases.

Keywords : Oceanography, Physics, Fluid Mechanics, Data Analysis, Energy, Environment

### Programme

«The planetary ocean» (2x2h + BE1) Typical scales, main basins. Earth motion. Pressure and sea-level variations. Properties of Sea Water, stratification. Differences between coastal and offshore.
«The moving ocean» (3x2h + BE2) Surface waves. Barotropic tides. Internal waves and tides. Gravity currents. Inertial waves, Rossby and Kelvin waves. Ekman layers and pumping. Vorticity. Global circulation. Stommel, El Niño.
«The living ocean» (1x2h) Ecosystems. Nutriments, turbulence biologic activity.
«The energetic ocean» (2x2h + BE3) Energy budget, forcings and dissipation. Parametrization. Thermal and hydrokinetic energy. Mining and drilling.

### Learning outcomes

- Understanding of the basic concepts in physical oceanography, in relation with the generic scientific background of the students.
- Make use of institutional databases to understand the physical environment in a given region of the oceans.
- Analyse and interpret in situ measurements, in regard with the present course materials, as well as with other sources of information.
- Garantee a global vision of the maritime environment, with the different physical, chemical, and biological factors to be involved.

### Independent study

Objectifs : [BE1] «The planetary ocean» : each group gets a different geographical region to study (topography, water masses, currents, tides).
[BE2] «The moving ocean» : students focus on a physical process in the region.
[BE3] «The energetic ocean» : the energetic aspects of the region are quantified, from a local or a global point of view depending on the region.

Méhodes : The BE will be held in the SkyLab rooms in order to easily visualize field data on large screens and to initiate collaborative work. Sutends will learn on the first module how to access public datasets (topography, currents, tides, water column) and to display them, before analyzing one region in details.

### Core texts

[1] Adrian E. Gill, *ATMOSPHERE-OCEAN DYNAMICS*, Academic Press (London), 1982
[2] Michèle Fieux *THE PLANETARY OCEAN*, EDP Sciences, Les Ulis, France, 2017
[3] Mark W. Denny*HOW THE OCEAN WORKS : AN INTRODUCTION TO OCEANOGRAPHY*, New Jersey : Princeton University Press, 2011

### Assessment

Final mark = 60% Knowledge + 40% Know-how
- Knowledge = 66% final exam + 34% continuous assessment (MCQ)
- Know-how = 100% continuous assessment (three reports of BE)

## *PARCOURS BÂTIMENT ET ARCHITECTURE*

## BUILDING & ARCHITECTURE

**Lecturers:** **Francesco FROIIO, Eric VINCENS**

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

Keywords :

### Programme

### Learning outcomes

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

### Assessment

## *PROPAGATION DES ONDES ÉLASTIQUES*

## ELASTIC WAVE PROPAGATION

**Lecturers:** Sebastien BESSET, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

In the field of Vibro-acoustics, the control of the behavior of structures is hampered by the difficulty of using the finite element method. In this way, wave propagation view is essential and condtitutes the basis of many analytical methods used in industry. Its implementation in the field of transport has made it possible to optimize the vibro-acoustic comfort of vehicles. In the field of Civil Engineering, the calculation of the vibro-acoustic behavior of buildings has been made necessary by the evolution of standards of safety and comfort. On the other hand, wave

Keywords : Propagation, vibroacoustics, radiation, seismic, stratified media, fluid-structure coupling.

### Programme

I - Introduction: Propagation of a mono-dimensional medium - Harmonic waves - Power flow
II - Wave analysis in solids: Propagation in a finite space - Propagation in a half-space - Waves in stratified media - Waveguide - Case of periodic media
III - Vibro-acoustic analysis: Non-modal behavior of structures - Integral formulation - Energy methods - Static analysis of dynamic problems
IV - Ground-structure coupling: Superficial foundations dynamics - Modeling of foundations

### Learning outcomes

- Understanding the main vibro-acoustic phenomena
- Understanding vibratory energy exchanges between elastic media
- Learn about the vibro-acoustic calculation tools used in mechanical design
- Understanding the seismic design rules

### Independent study

Objectifs : Learning and deepening a part of the course through a bibliographic analysis and reflection on an application problem.

Méhodes :

### Core texts

A. Bedford & D.S. Drumheller, *INTRODUCTION TO ELASTIC WAVE PROPAGATION.*, Wiley, 1994
F.E. Richard, JR Hall & R.D. Woods *VIBRATIONS OF SOILS AND FOUNDATION*, Prentice Hall, 1970
James F. Doyle*WAVE PROPAGATION IN STRUCTURES. SPECTRAL ANALYSIS USING FAST DISCRETE FOURIER TRANSFORMS - SECOND EDITION*, Springer, 1997

### Assessment

Technical study
Scientific paper study

## *PHYSIOLOGIE HUMAINE ET BIOTECHNOLOGIES*

## HUMAN PHYSIOLOGY AND BIOTECHNOLOGY

**Lecturers:** Emmanuelle LAURENCEAU

| Lecturers : 16.0 | TC : 0.0 | PW : 4.0 | Autonomy : 0.0 | Study : 8.0 | Project : 0.0 | Language : FR

### Objectives

The objective is to upgrade the basic knowledge in physiology and to enable understanding of the mechanisms of communication and regulation of the organism. Integration between the different functions will be tackled from concrete examples for biomedical applications based on the study of systems such as cardiovascular and immune systems. A second part will allow understanding the function of a living cell in its natural environment and to apprehend the potentialities of the cells and the biomolecules which compose them in the sectors of health. Emphasis will be placed on the link between structure, environment and ability to fulfill a biological function. The course will be illustrated by developments in molecular biology.

Keywords : cells, molecular biology, cardio-vascular and immune systems, biomedical applications

### Programme

Organization of the living cell
Organization of the human body: Cardiovascular, immune systems
Basic biological mechanisms
Cells in their environment
Lab: Analysis of grouwth cell
BE: Pharmacology
BE: Analysis of cardiac function by imaging

### Learning outcomes

- Know the basics in cellular and molecular biology Understanding the functioning of the human body and the structure-biological function relationships Understanding health sector issues Apply knowledge to problem solving

### Independent study

Objectifs : Preparation of the basic knowledge required for each course

Méhodes : Provision of a course handout

### Core texts

Alberts Bruce M. (Collab.) Johnson Alexander (Collab.) Lewis Julian (Collab.), *BIOLOGIE MOLÉCULAIRE DE LA CELLULE*, Flammarion Médecine-Sciences, 2004
Étienne Jacqueline *BIOCHIMIE GÉNÉTIQUE, BIOLOGIE MOLÉCULAIRE*, Masson, 2006
Silverthorn Dee Unglaub*PHYSIOLOGIE HUMAINE*, Pearson education, 2007

### Assessment

Evaluation of practical work = know-how
BE evaluation = methodology
Final exam = knowing

## *PHYSIQUE DES ÉCOULEMENTS TURBULENTS*

## PHYSICS OF TURBULENT FLOWS

**Lecturers:** Christophe BAILLY, Christophe BOGEY, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : AN

### Objectives

The course introduces different aspects of the physics of turbulent flows and associated modeling, and illustrates in a practical way some recent results from experimental and numerical studies. The main objectives are to master the basic concepts (generation/development of turbulence, turbulence boundary layer, local equilibrium, non-local role of vorticity, homogeneous and isotropic turbulence, Kolmogorov theory), to develop skills in turbulence modelling and in the analysis of results, as well as to provide an overview of experimental approaches.

Keywords : Turbulence, Reynolds number, turbulent boundary layer, vorticity dynamics, energy transfers, homogeneous and isotropic turbulence, Kolmogorov's theory

### Programme

1. Some general properties of turbulence, turbulent structure in spectral space, scales, time average and ergodicity; 2. Mean flow field: Reynolds decomposition, kinetic energy budget, closure by turbulent viscosity, examples and consequences; 3. Wall-bounded turbulent flows: log-law, closure models, phenomenology; 4 - Vorticity:definition, Biot & Savart, deformation, Helmholtz Eq., rapid distorsion theory, vortex pairing, enstrophy, helicicity; 5. Homogeneous and isotropic turbulence: two-point velocity correlation tensor, length scales, spectral tensor, isotropic, 1-D spectra, Taylor's assumption, energy spectrum, isotropic turbulence, Karman & Howarth relation, experiments, Kolmogorov's theory, Lin's eq.; 6. Flow field survey and visualization

### Learning outcomes

- Know the spatio-temporal description of turbulence
- Be able to describe and model some classical turbulent flows
- Know how to interpret the behavior of turbulent flows

### Independent study

Objectifs : Exercises are regularly proposed (two homework assignments freely chosen in a list, involving signal processing or the development of simple models using Matlab/Python among others), ...

Méhodes : ..., two lab work (TP) are also proposed (numerical simulation of channel flow and hot wire anemometer measurements in a turbulent round jet) as well as a final small class (BE).

### Core texts

Bailly, C. & Comte-Bellot, G., *TURBULENCE (IN ENGLISH)*, Springer, ISBN 978-3-319-16159-4, 2015
Davidson, P. A. *TURBULENCE*, Oxford University Press, Oxford, 2004
Pope, S.B.*TURBULENT FLOWS*, Cambridge University Press, Cambridge, 2000

### Assessment

Final mark = 50% Knowledge + 50% Know-how
Knowledge = 80% homework assignements + 20% lab work
Know-how = 40% homework assignements + 60% lab work

## *RECHERCHE OPÉRATIONNELLE ET OPTIMISATION*

## OPERATIONS RESEARCH

**Lecturers:** Abdel-Malek ZINE, Alexandre SAIDI

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

Keywords :

### Programme

### Learning outcomes

### Independent study

Objectifs :

Méhodes :

### Core texts

P. Venkataraman. Applied Optimization with Matlab. Wiley, 2009.
A. Billionnet. Optimisation discrète : De la modélisation à la résolution par des logiciels de progr
Michael Carter, Camille C. Price, Ghaith Rabadi*OPERATIONS RESEARCH: A PRACTICAL INTRODUCTION*, Chapman and Hall/CRC, 2017

### Assessment

## *RECONNAISSANCE ET COMPORTEMENT DES SOLS*

## SOILS SURVEY AND SOILS BEHAVIOUR

**Lecturers:** Eric VINCENS, Francesco FROIIO

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : FR

### Objectives

Any development is likely to disturb a natural balance and this risk must be able to be assessed by a in-depth knowledge of the site and the appropriate scientific tools.
The objectives of this course are:
- to give students the knowledge necessary to define and carry out a campaign to recognize soils of a site, this recognition will be supplemented by laboratory tests
- to present the analysis tools making it possible to assess the risks of instability of natural slopes or those built by

Keywords : soil, sand, clay, instability

### Programme

Experimental behavior of soils (clay + sands)
Soil recognition (in situ tests + laboratory)
Slope stability (static + dynamic)

### Learning outcomes

- master the different geomechanical and hydraulic models
- know how to analyze the stability of embankments and slopes
- understand the behavior of soils according to their nature

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

G. Olivari, *MÉCANIQUE DES SOLS*, ECL-SDEC polycopié
Ph. Mestat *DE LA RHÉOLOGIE DES SOLS À LA MODÉLISATION DES OUVRAGES GÉOTECHNIQUES* , 2000

### Assessment

- Lab experiments
- Final exam: closed-book examination
Grade : 2/3 final exam + 1/3 lab activities

# *REPRÉSENTATION ET MANIPULATION DE DONNÉES STRUCTURÉES*

# REPRESENTATION AND MANIPULATION OF STRUCTURED DATA

**Lecturers:** Daniel MULLER, Alexandre SAIDI

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

## Objectives

Understand how the XML ecosystem enforces fundamental Information System properties, such as organization, data integrity, application interoperability, or internationalization.

Keywords : Structured data, XML, DTD, XML Schema, Xpath, XSLT, Webservices

## Programme

Introduction
Structured Data – XML
Data Integrity – validation, DTD, schemas
Interoperability – Namespaces
Querying – Xpath, XQuery
Transformations – XSLT
Data exchange, Webservices – XML-RPC
Applications – SVG, XSL-FO

## Learning outcomes

- Compétence 2 - Composante 1

## Independent study

Objectifs : 1 - Design an XML application
2 - Transformations with XSLT
3 - Focus on a given application (SVG, XSL-FO, ...)

Méhodes : practical labs

## Core texts

Danny Ayers, Liam R.E. Quin, Joe Fawcett, *BEGINNING XML, 5TH EDITION*, Wrox, 2012
Ian Williams *BEGINNING XSLT AND XPATH: TRANSFORMING XML DOCUMENTS AND DATA*, Wrox, 2009
Amelia Bellamy-Royds, Kurt Cagle, Dudley Storey*USING SVG WITH CSS3 AND HTML5*, O'Reilly Media, Inc., 2017

## Assessment

50% knowledge: written exam without documents
50% know-how: mean of lab marks (1/3 each)

## *RÉSEAUX INFORMATIQUES*

## COMPUTER NETWORKS

**Lecturers:** René CHALON, Alexandre SAIDI

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

This course is presenting main concepts and protocols of computer networks. Design features and architectures of local area networks, medium and high speed networks as well as Internet protocols are systematically and methodically detailled. This conceptual and practical approach enables each one to better understand the current supply, the evolution and the prospect of present and future computers networks.

Keywords : networks, ISO model, Ethernet, Wi-Fi, Internet, IP, TCP, UDP, DNS, HTTP

### Programme

Lecture :
1- Introduction: main concepts, ISO model ans TCP/IP architecture
2- Physical layer: physical medium and data transmission
3- Local Area Network: topology, Ethernet, Wi-Fi
4- Network layer: internet principles, IP protocol, addressing, routing, IPv6
5- Transport layer: TCP, UDP, SCTP
6- Application layer: client/server model, DNS, e-mail, FTP, World Wide Web
Labs:
1- Detailed study of Ethernet with a netwok simulator

### Learning outcomes

- To know computer networks concepts
- To analyse and design Ethernet local aera networks
- To analyse and design TCP/IP based networks

### Independent study

Objectifs : Every student gets a personal licence of the network simulator for making the labs and designing his/her own network architectures

Méhodes :

### Core texts

G. Pujolle et al., *LES RÉSEAUX*, Eyrolles, 2018
D. Comer *INTERNETWORKING WITH TCP/IP - VOLUME 1, PRINCIPLES, PROTOCOLS AND ARCHITECTURE*, Pearson, 2015
C. Servin*RÉSEAUX ET TÉLÉCOMS*, Dunod, 2013

### Assessment

Final mark = 50% knowledge + 50% know-how
Knowledge = 100% final exam
Know-how = 100% continuous assessment

## *SIMULATION NUMÉRIQUE DES ÉCOULEMENTS*

## NUMERICAL FLOW SIMULATION

**Lecturers:** Christophe CORRE, Fabien GODEFERD, Marc JACOB

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

The goal of the course is to provide the students with an "advanced user / beginner developer" level in computational fluid dynamics, with a focus on compressible flows of interest in aerospace and energy applications. Following the course, the student should be able to properly select and apply a solution method for an engineering problem of practical interest and should understand the observed numerical behaviour (accuracy, robustness). The student will also be able to perform basic developments in existing CFD codes: change of boundary conditions or implementation of a new numerical flux.

Keywords : Classification of PDEs. Method of characteristics. Finite difference. Finite volumes. Centered and upwind schemes. Riemann solvers. TVD schemes. Structured and unstructured grids. Spectral methods.

### Programme

Lecture #1: Introduction to CFD. From pioneering works to 21st century challenges.
Lectures #2 and #3: Analysis of scalar problems : classification of PDEs, method of characteristics, finite difference schemes for model problems : 1D advection, 1D diffusion, 1D advection-diffusion.
Lectures #4 and #5: Extension of 1D finite-difference schemes to non-linear systems of conservation laws (Euler equations): from the 1st-order upwind scheme to high-resolution schemes.
Lectures #6 and #7: Finite-Volume Schemes in structured and unstructured grids. From Euler equations in Cartesian grids to the Navier-Stokes equations in triangular grids.

### Learning outcomes

- Understanding the current challenges of CFD. Applying the method of characteristics to analyze exact solutions of scalar conservation laws. Computing truncation erros and amplification factors for finite difference schemes applied to model advection, diffusion and advection-diffusion problems in one and several space dimensions. Implementing a numerical flux in a CFD code solving the traffic flow equation.
- Analyzing centered and upwind schemes for the solution of 1D Euler equations (smooth flows and flows including discontinuities). Selecting a relevant numerical scheme for the flow under study and using the proper tuning parameters for this scheme (artificial

### Independent study

Objectifs : Personal work on solved problems following the lectures: checking the good understanding of concepts and tools.
Personal work following the computer labs: ability to perform numerical development tasks, ability to perform, interpret and report on numerical experiments.

Méhodes : The 3 computer labs of 4h each are devoted to the presentation and application of the CFD codes provided. The students are prepared during these labs to the work which they will perform on their own, for 3 successive levels of difficulty: 1D scalar conservation law, 1D system of conservation laws, multi-D

### Core texts

Thomas H. Pulliam, David W. Zingg, *FUNDAMENTAL ALGORITHMS IN COMPUTATIONAL FLUID DYNAMICS*, Springer, 2014
Eleuterio F. Toro *RIEMANN SOLVERS AND NUMERICAL METHODS FOR FLUID DYNAMIC - A PRACTICAL INTRODUCTION*, Springer-Verlag, 2009
Charles Hirsch*NUMERICAL COMPUTATION OF INTERNAL AND EXTERNAL FLOWS - THE FUNDAMENTALS OF CFD*, Butterworth-Heinemann, 2007

### Assessment

Grade = 40% knowledge (final exam) + 60% know-how (reports on computer labs)
Knowledge grade = 100% final exam grade
Know-how grade = 100% average of the 3 computer labs reports

## *STABILITÉ DES SYSTÈMES MÉCANIQUES*

## STABILITY OF MECHANICAL SYSTEMS

**Lecturers:** Jean-Jacques SINOU

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

When designing structures and mechanical systems, it is imperative to control the risks of instability arising from many phenomena. Mention may in particular be made of the various couplings of a non-conservative nature related to the existence of friction or of contact between a moving elastic structure and a fluid or a solid. Moreover, the phenomena of buckling and blistering are increasingly dimensioning given the lightening of the structures associated with the use of new materials. In the fields of transport, civil engineering and energy, we can cite: brake noise, resistance to crashes, instabilities of rotating machines, risk of building collapse, stability of drilling systems.

Keywords : Stability, brake squeal, fluid-structure, rotating machines, aeroelastic coupling, hydro-elastic coupling

### Programme

I. Introduction and illustration from industries
II. Buckling of elastic structures
III. Non-conservative elastic structures
IV. Stability of mechanical systems and vibration
V. Practical methodology in engineering and research units.
VI. Applications to mechanical systems with friction and structures coupled with flow

### Learning outcomes

- Develop a synthetic vision of the risks of instabilities of mechanical systems in the design process
- Learn about computational tools to predict instabilities
- Understand the coupling phenomena at the origin of the instabilities

### Independent study

Objectifs : Learning and deepening part of the course.

Méhodes : Bibliographic analysis and reflection on a problem of application

### Core texts

Wanda Szemplinska-Stupnicka., *THE BEHAVIOR OF NONLINEAR VIBRATING SYSTEMS VOL 1. FUNDAMENTAL CONCEPTS AND METHODS : APPLICATIONS TO SINGLE-DEGREE OF FREEDOM SYSTEMS.*
Robert D. Blevins. *FLOW-INDUCED VIBRATION*
Roland Bigret*STABILITÉ DES MACHINES TOURNANTES ET DES SYSTÈMES*

### Assessment

## *STATISTIQUE APPLIQUÉE AUX SCIENCES DE L'INGÉNIEUR*

## STATISTICAL ENGINEERING

**Lecturers:** Céline HARTWEG-HELBERT, Alexandre SAIDI

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

The objective of this course is to provide the classic tools of mathematical statistics which includes the choice of the probabilistic model, its estimation and its evaluation. We will be particularly interested in the linear model and its extensions in the context of high-dimensional statistical learning (LASSO, RIDGE, PCR PLS), the logistic model and tree-based models (CART, RF, Boosting etc. ). The aim of this course is also to provide training in the manipulation of data and the practical implementation of the studied models. For this, a substantial part of the course is oriented towards the implementation of the different models using the R software through the study of a large number of examples.

Keywords : Linear and logistic regression. Model selection. Design of experiments. L1 L2 Penalized regression. Regression trees.

### Programme

1) Linear regression. Validities and limitations of the method. Model selection.
2) Design of experiments: screening and response surface
3) Logistic regression
4) Elements of statistical learning in high dimension
5) Clustering

PRACTICAL ACTIVITIES
The three activities will be devoted to learning the techniques of regression models on the R software. Numerous data sets will be studied.

### Learning outcomes

- Know how to recognize different classes of statistical learning problems.
- Know how to implement basic models of statistical learning and validate their relevance.
- Know how to propose learning methods adapted to the high dimension
- Know how to use R.

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

G. Saporta, *PROBABILITÉS, ANALYSE DES DONNÉES ET STATISTIQUE*, Technip, 2020
T Hastie, R Tibshirani, J Friedman *THE ELEMENTS OF STATISTICAL LEARNING: DATA MINING, INFERENCE, AND PREDICTION*, Springer, 2009

### Assessment

Final mark = 60% Knowledge + 40% Know-how
Know-how = 100% continuous assessment
Knowledge= 100% final exam

## *SYSTÈMES EMBARQUÉS SÉCURISÉS*

## SECURE EMBEDDED SYSTEMS

**Lecturers:** Cédric MARCHAND

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : MI

### Objectives

Embedded systems are everywhere, whether in our pockets, homes or cars, but also in industry, aeronautics or the space sector. More and more of these systems are used in applications where the data handled is sensitive and must be protected. With the increase of Internet of thins ecosystems, a particular interest in security problems arises among the general public, notably with contactless payment, connected electricity meters, home automation, etc.

Throughout this course, we will discuss the basic principles of security as well as their integration into

Keywords : Embedded System, Security, cryptography, hardware attacks and countermeasures

### Programme

This module is divided in 8*2h of lectures and 2*4h of practical sessions. A 4h session is also used to prepare the practical sessions.

First, we introduce basical notions of embedded systems and security with 3 lectures:
1 - Introduction course : definition of embedded system, security and global challenge and opportunities
2 - Introduction to embedded systems, microcontroller and FPGA
3 - Introduction to cryptography

### Learning outcomes

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

### Assessment

Final mark = 70% knowledge + 30% Know-How
Knowledge mark = 100% final exam
Knw-how mark = 100% continuous assessment

## *SYSTÈMES D'INFORMATION EN ENTREPRISE*

## ENTERPRISE INFORMATION SYSTEMS

**Lecturers:** Romain VUILLEMOT, Alexandre SAIDI, Charles-Edmond BICHOT

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : FR

### Objectives

Keywords :

### Programme

### Learning outcomes

### Independent study

Objectifs :

Méhodes :

### Core texts

Yves Caseaut, Gérard Roucairol, *URBANISATION, SOA ET BPM : LE POINT DE VUE D'UN DSI*, Broché, 2008
Christophe Longépé *LE PROJET D'URBANISATION DU SI*, Lavoisier, 2009
Jacques Printz et Yves Caseau*ARCHITECTURE LOGICIELLE : CONCEVOIR DES APPLICATIONS SIMPLES, SÛRES ET ADAPTABLES*, Dunod, 2009

### Assessment

## *SYSTÈMES DE BASES DE DONNÉES*

## DATABASE SYSTEMS

**Lecturers:** Mohsen ARDABILIAN, Alexandre SAIDI, Daniel MULLER

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : MI

### Objectives

Databases are at the heart of all information systems that are nowadays omnipresent in our everyday life (work, organization, web, etc.). The aim of this course is to study the principles of relational and semi-structured database programming that are the foundation of any application in the various information systems. It also discusses the implementation aspects of database systems such as concurrency control or query optimization.

Keywords : databases, structured data and non structured data modelling, data storage and access, relational languages, concurrency control, query optimization, integrity constraints

### Programme

Introduction (relational models, schems, SQL, semi-structured models, XML)
Data models (entitty/relationship, relational, object)
relational languages (relational algebre, SQL, Datalog)
SQL Programming (PL/SQL, Embeded SQL)
Database systems and application Web (JDBC, PHP)
XML-WPath-Wquery-Xslt
transactions and concurrency control
Query optimisation
Integrity constraints

### Learning outcomes

- Understand the major components of modern information systems
- Know how to make use of fundamental techniques to develop information systems and applications

### Independent study

Objectifs : Three assignments practical work are scheduled to develop a database system, extract data through SQL and develop a Web information system for a particular data management application

Méhodes : use of MySQL

### Core texts

H.Garcia-Molina, J.D.Ullman, J.Widom, *DATABASE SYSTEMS: THE COMPLETE BOOK*, Pearson Prentice Hall, 2002
Georges Gardarin *BASES DE DONNÉES (HTTP://GEORGES.GARDARIN.FREE.FR/LIVRE_BD_CONTENU/XXTOTALBD. PDF)*, Eyrolles, 2003

### Assessment

40% written test, 60% assignments of practical work

## *TRAITEMENT ET ANALYSE DES DONNÉES VISUELLES ET SONORES*

## PROCESSING AND ANALYSIS OF VISUAL AND AUDIO DATA

**Lecturers:** Mohsen ARDABILIAN, Alexandre SAIDI, Céline HARTWEG-HELBERT,

| Lecturers : 16.0 | TC : 0.0 | PW : 0.0 | Autonomy : 0.0 | Study : 12.0 | Project : 0.0 | Language : MI

### Objectives

The processing and analysis of visual and audio data are basic approaches in computer vision and audition. Based on Artificial Intelligence techniques, they are developed and applied with the aim of endowing machines with the ability to see, hear and acquire a high level understanding of the content of digital images, sound, and videos. From an engineering perspective, the goal is to automate the tasks that the human visual and auditory system can perform with applications in many fields: Art, Audiovisual, Machine Vision, Autonomous Vehicles, Medicine, Surveillance, Military , etc.

Keywords : Image analysis, video analysis, audio analysis, AI, feature, descriptor, shape, color, texture, classification, recognition, fusion, image processing, super resolution, Big Data

### Programme

Content-based image and/or sound retrieval
Assessment of image and sound analysis, and processing approaches
Image processing algorithms, super resolution
Audio processing algorithms
End-to-end image and sound analysis algorithms

### Learning outcomes

- To be able to apply the appropriate processing algorithms to a given context
- To be able to apply the appropriate analysis algorithms to a given context
- Evaluate algorithms or processing and analysis systems
- Know the state-of-the-art processing and analysis algorithms, as well as their principles

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

R. Szeliski, *COMPUTER VISION -- ALGORITHMS AND APPLICATIONS*, Springer, 2010
A. Divakaran *MULTIMEDIA CONTENT ANALYSIS: THEORY AND APPLICATIONS*, Springer, 2008
R. O. Duda, P. E. Hart & D. G. Stork*PATTERN CLASSIFICATION*, Wiley Interscience, 2004

### Assessment

Final mark = 60% Knowledge + 40% Know-how
Knowledge N1 = final exam
Know-how N2 = continuous assessment

## *TRIBOLOGIE : PRINCIPES ET APPLICATIONS*

## TRIBOLOGY

**Lecturers:** Denis MAZUYER

| Lecturers : 16.0 | TC : 0.0 | PW : 8.0 | Autonomy : 0.0 | Study : 4.0 | Project : 0.0 | Language : MI

### Objectives

About 25% of the energy consumed by mankind is lost in contact between moving surfaces. This figure shows that understanding the tribological phenomena of friction, lubrication and wear is necessary to meet the technological challenges of sustainable production and the reliability of consumer goods or energy frugality. At the crossroads of mechanics, physics and chemistry of materials, this course gives the principles and methods of surface engineering used in tribology to design complex interfaces in biological implants, mechanical assemblies of propulsion and power transmission or manufacturing processes.

Keywords : Friction, lubrication, surface engineering, contact mechanics, materials science

### Programme

I. The mechanics of static contacts: Contact between smooth and rough surfaces, Role of thin solid films and coatings
II. Macroscopic laws of friction and wear: Static and kinetic friction, Physics of friction and wear
III. Surfaces and lubricants: Adhesive contacts, Structure and properties of lubricants and additives
IV. Thin film lubrication: Experimental and computational hydrodynamics, Elastohydrodynamic lubrication in high-pressure contacts
V. Boundary lubrication: Control of friction and wear, Nanotribology and molecular

### Learning outcomes

- To analyse an industrial problem in tribology and to propose a dignosis
- To characterize features of rough urfaces and liquid lubricants as they pertain to interface sliding.
- To suggest solutions for suitable applications based on improved materials selection, use of tribological coatings, improved desgin or lubrication.
- To apply the basic theories of friction, wear and lubrication to predictions about the tribological behavior of commonly encountered sliding interfaces.

### Independent study

Objectifs : This activity is not concerned with framed autonomy activities outside personal work.

Méhodes : This activity is not concerned with framed autonomy activities outside personal work.

### Core texts

G.W. Stachowiak, A.W. Batchelor, *ENGINEERING TRIBOLOGY*, Butterworth - Heinemann, 2014
I.L. Singer, H. M. Pollock *FUNDAMENTALS OF FRICTION: MACROSCOPIC AND MICROSCOPIC PROCESSES*, Springer Netherlands, 1992
F.P. Bowden, D. Tabor*FRICTION AND LUBRICATION OF SOLIDS*, Oxford University Press, 1954

### Assessment

Final mark = 2/3 Knowledge + 1/3 Know-how
> Knowledge N1 = 100% final exam
> Know-how N2 = 100% continuous assessment