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PICSEL

Embedded Systems

Prerequisites: No

Learning Objectives

A new generation of systems rich in sensors and massively distributed is emerging, which will have a very important economic and environmental impact. There are many applications involved, including autonomous cars, aerial and submarine drones, factory automation systems, intelligent environments, sensor networks, space probes, etc. In most of these applications, reconfigurable integrated systems are needed that will operate autonomously for years in difficult and uncertain environments, reaching unprecedented levels of skill and robustness. The design and realisation of these intelligent embedded systems requires a software revolution that brings together a variety of computational methods ranging from artificial intelligence, software engineering, operational research and control.
This module covers the principles of embedded systems and the methods of designing, prototyping and making such systems. In addition to the physical aspects, the module offers students a set of design tools that are essential for prototyping and the realisation of embedded systems in a wide range of applications.

Programme Description

1. Introduction
   - Specifications and Constraints, Sample Applications
   - Classification and Architectures
   - Embedded System Safety
2. Acquisition
   - Sensors, data acquisition, interfacing, memories
3. Processing
   - Microprocessors, SoC, architecture
   - Architecture of computers
   - Function in a CPU, memory access, programming in C (TP) language
   - Parallel numerical computing (CPU, GPU), threading, CUDA
   - Programmable logic and programming in VHDL (TP)
   - CAD tools Quartus and Modelsim (TP)
   - Prototyping in FPGA
   - Programming Spartan 3A FPGA (TP)
   - Microcontrollers: Arduino, Raspberry Pi, NodeMCU
   - Bus and communication protocols: I2C, SPI, UART,...
   - Use of C language classes
   - Scrutiny / interrupt management
   - Application: collecting sensor data Connected Objects

4. Connected Objects
   - Embedded System Connectivity: NB-IoT, LTE-M and LPWAN networks
   - Energy consumption

5. Sample applications
 - Sensor networks, smart-home
6. Seminars (external)

Target generic centrale-specific field-related skills and knowledge

The significant and steady advances in performance, flexibility, programmability and cost reduction of electronics create significant opportunities for innovation in the embedded systems field. At the same time, the industry has difficulties in finding skills in this field and faces major challenges in integrating the software and hardware aspects.
Employers are in particular companies that develop electronic components and embedded systems in different fields.

Knowledge Control Procedures

Continuous monitoring, mini-projects, practical work noted

Bibliography

J. K. Peckol, *Embedded Systems: A Contemporary Design Tool*, Wiley, 2019.
M. Wolf, *Embedded System Interfacing: Design for the Internet-of-Things and Cyber-Physical Systems*, Elsevier, 2019.
E. Grolleau et al., *Introduction to Embedded Real-Time Systems: design and implementation*, Dunod, 2018.

Teacher

- Ali Khalighi
- Nicolas Bertal
- Fabien Lemarchand
- Michel Moulin
- Outdoor speakers

Sustainable development objectives (SDO)

7-Use of renewable energy
9-Building Resilient Infrastructure
11-Sustainable cities and communities
13-Combating climate change
14-Aquatic Life

Distribution of hours

Total: 80
Magistrates: 46
Practical work: 34
Projects: 2

Language(s) used during the course: French and English

MECA

Geophysical flows

Prerequisites: No

Learning Objectives

- To acquire knowledge and skills in the field of fluid mechanics applied to atmospheric and oceanic flows, waves, tsunamis and other maritime
hazards - To understand the physical mechanisms and processes governing these phenomena, in order to be able to use modelling tools (numerical or experimental), to analyse observed effects on the natural environment (e.g. coastal erosion) or on anthropogenic structures (e.g. digestive Harbour, Wind at Sea)
- To acquire sufficient scientific knowledge to integrate a project team on ocean, river or atmospheric
fields - To develop a critical understanding of the broad study tools used to study, model or predict these flows and waves in ocean, coastal or river environments. Making the most of these study tools and methodologies, using them to the best of their ability and maintaining a critical sense of the results achieved

Programme Description

Wave dynamics and extreme waves:
- Main physical processes involved in the generation of waves and their spread from the ocean to the coast.
- Theories for the kinematics of waves (speeds, pressure, etc.)
- Transformation of waves into coastal zone and surge
- Interactions of waves with harbour
structures and agitation- Extreme waves (celeriates): mechanisms of formation and characterisation
- Different types of mathematical models for sea states and waves (principles, assumptions, limitations, examples of results, etc.)
Geophysical and hydraulic flows:
- Physics of large-scale flows in the atmosphere and ocean (Earth rotation effects)
- Notion of atmospheric dynamics and meteorology
- Instabilities for geophysical flows Sci
- Astronomical Tides and Weather
Overcounts- River and River Flows (River Waves, Thresholds and River Works Effects, etc.)

Target generic centrale-specific field-related skills and knowledge

- Transmit expertise on the physics and modelling of waves, tsunamis, and waves in the marine environment and of open-surface atmospheric and hydraulic flows (C2)
- Give keys to understand the physical mechanisms that govern these flows and waves, their dynamics, and their interactions with natural terrain and structures (civil engineering structures of harbour or or coastal type, environmental issues, etc.) (C2)
- Transmit notions enabling Making the best choices in terms of tools to use for projects or studies, issuing specifications, interpreting results in a meaningful way (C3)

- Having a sufficient level of proficiency to propose, stimulate or discuss innovations in these areas (C1)

Knowledge Control Procedures

CC1 - written examination with authorised documents on the "Wave dynamics" part: 50%
CC2 - written examination with authorised documents on the "Geophysical and Hydraulic Flow" section: 50%

Bibliography

P. Bougeault, R. Sadourny, *Ocean and Atmospheric Dynamics*, Éditions de l'École Polytechnique, 2001.

Teacher

- Michel Benoit, Prof. Fluid Mechanics and Hydrodynamics (44 h)
- Hubert Branger, CR CNRS, physical oceanography (4 h)

Distribution of hours

Total: 24
Magistrates: 18
Directed work: 6
Practical work: 4

Language(s) used during the course: French

PICSEL

Space Technology

Prerequisites: No

Learning Objectives

The design, realisation, validation and exploitation of space instruments, whether for Earth observation or for the sciences of the Universe, requires the implementation of specific technologies and techniques at all stages of a space project. These allow the realisation of instruments not only adapted to the severe environment, but also satisfying the consequent requirement of reliability.
The objective is to present the specific techniques in this field, as well as the associated advanced technologies, which will be presented by taking as an example the design and the realisation of an observation instrument for astrophysics. This will also include the application of these to Earth observation missions or other industrial fields.

Programme Description

Following a presentation of the context and the basis for the preparation of a space mission, in particular in terms of phase, maturity level (TRL) and quality, as well as the variation of the specific constraints of space on associated techniques and technologies, the programme developed will be as follows:
- System engineering: presentation of important aspects in the analysis and design of a space optomechanical system, from the establishment of specifications to the establishment of an error budget and the estimation of performance.
- Spectral analysis techniques: This module aims to introduce the different spectral analysis techniques used in astrophysics, but which are also found for some in other fields, including industry.
- Wavefront control: Presentation of the various techniques for controlling and maintaining the quality of the wavelength of a telescope or space instrument (active optics/spatial adaptive).
- Space optomechanics: design of a space optomechanical system, from its definition, through its thermomechanical modelling and the insertion of actuation and measurement systems, to the preparation of functional tests.
- Assembly, integration, testing/validation: This module will address the qualification phase of a space instrument or system, including the various tests in environments (empty, thermal, vibration) carried out during the integration and subsequent validation of the system.

Target generic centrale-specific field-related skills and knowledge

- Theme 2: Complex Systems and
ComplexitySpace instruments are by nature extremely complex instruments by their technical nature and by their design, integration and validation. These courses will allow students to address this complexity.
- Theme 3:
ProgramsSpace missions are designed under national or international programmes. These lessons will provide an opportunity to address the scientific and technical aspects.

Knowledge Control Procedures
Continuous

Bibliography
Course notes and working papers provided by the teaching team.

Teacher
- Teachings provided by the astronomers and engineers of the Marseille Astrophysics Laboratory, with stakeholders from Airbus, CNES, ESA, ONERA and Thales.
-Responsible: Marc Ferrari, Éric Prieto

Distribution of hours
Total: 80
Magistrates: 66
Directed work: 6
Practical work: 8

Language(s) used during the course French

GREEN

Energy and Industry

Prerequisites: No

Learning Objectives

This EU develops and deepens the themes of the 1st year general course MGP2. The focus is on practical problem-solving methods from the industrial field, and in particular from process engineering, so that a practical problem of thermal transfer can be addressed and dialogue with the specialists or research offices involved in this field (process engineering operations, exchangers, ovens, building thermal, cooling of electronic components, etc.).

Programme Description

SESSION 1: CONDUCTION (1)
- General concepts of heat transfer, usual units
- FOURIER Law - General heat equation – Limit conditions
- Conductivity: orders of magnitude, measurements
- Application to flat and cylindrical geometries
- Conduction with source
- Transfers in permanent 2D: FORM coefficients SESSION 2 (a): CONDUCTION (2)
- Dynamic Transfers (Number of Biot, Fourier)
- Thermally thin bodies in dynamic
regime- Dynamic Transfers (semi-infinite wall, flat wall, cylinder)

SESSION 2 (b): CONVECTION (1)
- Definitions of convective phenomena, orders of magnitude
- Dimensional analysis and numbers without dimension
- Relationships usable in forced convection and natural convection

SESSION 3 (a): CONVECTION (2)
- Definition of convective phenomena, orders of magnitude
- Dimensional analysis and numbers without dimensions
- Relationships usable in forced convection and
natural convectionSESSION 3 (b): AILETTES
- Types of fins and definitions
- Efficacy of fins
- Practical method of calculation

SESSION 4: EXCHANGERS
- Main types of exchangers - Definitions
- Logarithmic deviation of the counter-current and co-current exchangers
- Other types of exchangers, correction factor Ft
- Number of transfer units and efficiency functions
- Exchanger networks

SESSION 5: RADIATION (1)
- Definitions, laws of the black body, emittance

- Kirchoff law, emissivity, absorptivity
- Radiation between parallel grey planes
SESSION 6: RADIATION (2)
- Radiation between finished black surfaces (shape factors)
- Gray body, real bodies
- Radiance, calculation of the enclosures with grey walls

Target generic centrale-specific field-related skills and knowledge

As the MGP1 and 2 Mechanics modules remain general and theoretical, this module aims to put basic knowledge into practice in an engineering approach, where development objectives take into account new constraints. The management of various parameters for the search for a viable and optimal solution is addressed here.
This course allows to implement and synthesise a diverse set of knowledge (thermal, mathematical, physical transfers) within a cross-disciplinary framework with many possible fields of application. The new skills acquired are cross-cutting and enable the Central Engineer to have versatile tools for sizing and managing thermal systems.

Knowledge Control Procedures

3h review: 100%

Bibliography

Course documents copied with thermophysical value tables.
Franck P. Incopera, *Fundamental of Heat and Mass transfer*, MacGraw-Hill.
Bruno Chéron, *Thermal Transfers*, Ellipses.
Thermal Atlas, VDI.

Teacher

- Daniel ROUX

Distribution of hours

Total: 25
Magistrates: 12
Directed work: 13

Language(s) used during the course French

GREEN

Water and Industry

Prerequisites: No

Learning Objectives
-Analyse effluent data and propose appropriate
processes- Dimensionize simple water
cleaning processes- Understand the environmental impact of industrial effluents

Programme Description
- Introduction to the Environmental Problem of Industrial Releases
- Study of the Classic Water Treatment Process
- Study of processes specific to industrial influences and effluents
- Dimensioning of treatment processes according to the pollutant load and the desired water quality

The restitution and evaluation will take place in the form of a case study conducted in a supervised project, by group.

Knowledge Control Procedures
Review: 100%

Bibliography
Course Slides

Teacher
- Audrey Soric

Distribution of hours
Total: 25
Magistrates: 12
Directed work: 13

Language(s) used during the course French

GREEN

Supramolecular chemistry

Prerequisites: No

Learning Objectives

The goal is to get students to see beyond molecules, that is, how interactions between molecules govern many chemical, biological or physical processes and can be leveraged to build objects with remarkable properties: nanocatalyzers, materials with variable properties, molecular cages... The links between supramolecular chemistry and biology or physics will be highlighted to show how this chemistry can provide elegant solutions to key issues: understanding of the mechanisms of neurodegenerative diseases (Alzheimer), bioprobes (cancer detection), new strategies to fight cancer, non-linear optics, molecular electronics ... This EU, which will start from the ground up to apply, will also allow students to connect the different aspects of chemistry (organic, spectroscopy, thermodynamic kinetic...) and to establish links with other disciplines (physics and biology).

Programme Description

- Concepts
- Molecular topology
- Recognition of neutral anions, cations and molecules
- Cooperativity
- Applications for the recognition of molecules of biological interest (neurotransmitters, sugars), interest in biology
- Stereochemistry and supramolecular chemistry
- Bioinspired chemistry
- Supramolecular chemistry in water
- Supramolecular catalysis: Obtaining Nanoreactors
- Molecular Nodes, Rotaxanes, Catenanes
- Molecular Electronics
- Molecular Machines
- Biosondes
- Supermolecular
- Materials- Responsive materials

Target generic centrale-specific field-related skills and knowledge

-1b. Ability to expand a tool or concept to other uses
-1e. Ability to collect and analyse information using logic and method
-2a. Ability to understand and formulate the problem (assumptions, orders of magnitude, etc.)
- 2c. Ability to recognise specific elements of a problem
- 2nd. Ability to propose one or more resolution scenarios

Knowledge test procedures

Writes 2 hours: 100%

Bibliography
Books of the documentation centre. Paper.

Teacher
- Alexandre Martinez
- Bastien Chatelet

Distribution of hours
Total: 25
Magistrates: 13
Directed work: 12

Language(s) used during the course French

GREEN

Organic chemistry

Prerequisites: No

Learning Objectives
Have all the knowledge necessary for a Central General Engineer wishing to start an industrial or academic career in the field of chemistry.
Consolidate and complete the base of the knowledge acquired in Chemistry by the students of the School.

Programme Description
- Part 1: Structure and reactivity, hydrocarbons, C-X-bound compounds, aromatic, carbonyl function
- Part 2: Asymmetric synthesis, pericyclic reactions and Woodward and Hoffman rules

Knowledge Control Procedures
Examination 2h: 100%

Bibliography
Some sections of the course are accompanied by booklets. Books in the documentation centre and online resources.

Teacher
- Laurent Giordano

Distribution of hours
Total: 25
Magistrates: 13
Directed work: 12

Language(s) used during the course French

GREEN

Biotechnologies

Prerequisites: No

Learning Objectives
Biotechnology education should provide a culture in the field of life biochemical reactions to serve as a model for the implementation of innovative projects based on cellular biology. Revisions of the basics of molecular biology and their use for biotechnology.

Programme Description
- Molecular biology in the living world
- Molecular biologist toolkit
- Examples of biotechnology

Target generic centrale-specific field-related skills and knowledge
- Ability to invent creative, ingenious and original solutions
- Ability to expand a tool or concept to other uses
- Ability to stimulate imagination
- Ability to mobilise a scientific/technical culture (transdisciplinarity and/or specialisation)

- Study the world of life to be inspired by it in order to reproduce certain processes
- Ability to bypass certain limits of chemistry by putting bioconversions or green chemistry into play- Living World Action
- Knowing how living world works to find alternatives to chemistry through biotechnology

Knowledge Control Procedures
Examination 2h: 25% (Authorised Documents and Calculator)
Continuous MCQ: 75%

Bibliography
In progress: Courses corresponding to the PowerPoint slide show. Also available online.

Teacher
- S. Cannaan

Distribution of hours
Total: 25
Magistrates: 12
Directed work: 8
Practical work: 5

Language(s) used during the course French

GREEN

Bioprocesses

Prerequisites: No

Learning Objectives

The EU uses process engineering fundamentals (balance sheets and kinetics) and microbiology fundamentals (metabolism, growth kinetics) to develop models adapted to the specificities of living micro-organisms.
The EU thus allows to approach the sizing of several typical unit processes using micro-organisms.
This module is concerned with the implementation of processes producing or using living micro-organisms. It
adapts the classical tools of process engineering to unit operations adapted to the production of micro-organisms or molecules synthesised by these micro-organisms. It thus allows to define operating conditions that can be used in industrial practice. The modelling approach developed in a first part is then implemented during a practical session.

Programme Description

The content of the module has been modified to introduce a practice session. The skills and knowledge sought are, on the one hand, to know the main characteristics of a process involving micro-organisms, and on the other hand, to know how to size the key elements of the process: Bioreactor, its agitation and its aeration, the sterilisation of food supplies.
Teaching plan:
- Applications of biotechnology (general presentation,
documentary research and conference on microalgae)
- Biological material: metabolism, modelling of cell behaviour: stoichiometry and growth kinetics
- The typical unit operations of bioprocesses
- The bioreactors (specificities, culture in continuous agitated reactor ideal, aeration, agitation)
- The upstream and downstream operations: sterilisation, purification, protein extraction and extrapolation
- 8-h session of practical work (IUT Saint-Jérôme), with data pooling between binomials

Target generic centrale-specific field-related skills and knowledge

- Recognise the specific elements of a problem and extend a tool or concept to other uses - Solve complex and transdisciplinary problems, namely, understand a problem, formulate it, model it using concepts and arrive at an acceptable solution -Know how to collect and analyse information in a poorly controlled field

Knowledge Control Procedures

Examination 2h: 50% Calculator
DocumentsTP CC Report: 30 %
CC Abstract + Presentation 5 min: 20%

Bibliography
Exercise book, PPT presentations, bibliography.

Teacher
- Audrey Soric
- Cristian Barca
-Florian Delrue

- Stéphane Canaan

Distribution of hours
Total: 25
Magistrates: 9
Directed work: 8
Practical work: 8

Language(s) used during the course French

GREEN

From Resource to Product: disposal

Prerequisites: No

Learning Objectives

Education Unit "From Resource to Product: immersion" is intended to enable students to be confronted concretely, through conferences conducted by professionals and through company visits, with the different industrial realities that may be theirs after their training at the Central School.

The schedule of conferences and visits may vary from year to year. For information, the following activities took place during the year 2013 - 2014:
- Visit of a refinery (Inéos)
- Visit of an industrial effluent treatment plant (OTV)
- Visit of an active ingredient production plant (Sanofi Chimie)
- Introduction to process design (Pascal Denis - ECM)
- Conference on REACH (Pierre Michiel - ADER Méditerranée)
- Conference on the economic evaluation of processes (Jean-Richard Llinas - Consultant)
- Conference on the management of environmental risks in an ICPE (Jean-Frédéric Beuvin - ARKEMA)

- Conference on the formulation (Renaud Canaguier - NIXE)
- Conference on case studies in the The Pharmaceutical Industry (▪ÉdithNorrant - UCB Pharma)
- Conference on Life Cycle Analysis (Nicolas Minard - Carma)

Target generic centrale-specific field-related skills and knowledge

- Ability to analyse the context (organisational, institutional, societal, merchant)

- Ability to mobilise a scientific/technical culture (transdisciplinarity and/or specialisation)
- Ability to recognise the specific elements of a problem

- Ability to identify interactions between elements
- Ability to rapidly deepen a field
- Ability to integrate quality/safety/environmental rules and standards

- Ability to take into account societal, legal, financial, economic, regulatory issues

- Ability to take into account the international dimension

- Knowledge of concrete cases in which the skills they have acquired during their training are used to address real problems.

Teacher

- Pascal Denis
- External stakeholders

Distribution of hours

Total: 34
Courses: 34

Language of the course: French

PICSEL

Images: Training, Perception and Representation

Prerequisites: No

Learning Objectives

The purpose of this module is to present the essential links of an imaging chain: from the fundamentals of image training to the material technologies to acquire and then render the image to the human, through the processing and analysis of images by a machine to extract the information. It will provide the basic knowledge of each of the technological bricks of this chain and the fundamental elements concerning human and machine vision.
These achievements can be used to understand, size, develop and integrate applications in the field of imaging.

Programme Description

Whether in the industrial, medical, scientific or everyday realms, image is at the heart of many systems and applications:
- Medical imaging that plays a key role in the diagnosis, monitoring and treatment of human diseases- Augmented reality and 3D display technologies that transform the interaction of humans with their environment
- Autonomous systems based on the integration of artificial intelligence algorithms and Data Processing for Vision
Systems- Sources of Observation, Risk Prevention, Environmental Monitoring from Embedded (Drone) or Satellite
Imaging- Industrial Vision for Quality Control, Observing in a hostile environment, Robotics...

The course is structured in several sequences:
- Physical Bases of Image
Formation- Image
Sensors- Visual

Perception- Systems display▪Processing of the imagesCourses will be complemented by practical, experimental work on the Photonic platform and digital work on PC.

Target generic centrale-specific field-related skills and knowledge

Engineers capable of working on complex imaging-based systems, whether to implement an imaging chain for an application, processing from digital images, tracking business or projects implementing complex image and multimedia acquisition and processing systems.

Knowledge Control Procedures

Continuous

Teacher

- Caroline Fossati
- Laurent Gallais-During (in charge)
- Frédéric Lemarquis
- Muriel Roche

Distribution of hours

Total: 80
Magistrates: 54
Practical work: 26

Language(s) used during the course French

DIGITAL

Development Methods

Prerequisites: No

Learning Objectives
- Summary: Code option. It aims to learn how to define, create and maintain a web application, service or API. Following this option, the student will be able to choose the methods and frameworks appropriate to their creation, maintenance and evolution.

- Audience: You don't have to be a computer enthusiast, but you don't have to be afraid to read some documentation and have nothing against coding. Lessons are being learned to keep pace whether you are comfortable with the concepts presented or need to be upgraded.

Programme Description
The 3-point programme:
- Development methods:
- test driven development (applications in js, python and java)
- source control (applications with git and github)
- devops (application with a dedicated and ansible ovh server)
- Web server:
- web server 101 (applications in node.js and JavaScript)
- API rest and micro-services (applications with flashes) ask and python)
- robust services and continuous improvement (application with springboot and java)
- mobile applications (applications with Android and java)
- Network:
- principles and administration of a local network (applications with packettracer)

Target generic centrale-specific field-related skills and knowledge
Scientific and technical innovation: use of current methods and practices in development.
Control of complexity and systems: IT is THE science of complexity. This EU is therefore particularly focused on this competence.Programme
Direction: the creation and maintenance and continuous improvement of computer programmes.
Management of Men: rather an introspection, a way to discover its strengths and weaknesses as a developer.

Knowledge Control Procedures
Continuous

Teacher
- Brucker

Distribution of hours

Total: 100
Magistrates: 83
Directed work: 17

Language(s) used during the course French

GREEN

From Resource to Product: principles

Prerequisites: No

Learning Objectives

This module is in two parts. One deals with analytical methodology and intends to give basic knowledge on analytical techniques and practice some of them.
The students will have to work on mini projects. They will have to do bibliographic research, define a method of analysis and apply it. They will also provide written and oral report.
The other part is dedicated to industrial chemistry and aim at discovering important concerns in modern chemical industry through a bibliographic study of the subject. they will make an oral presentation.
Summary of Learning outcomes
- Analytical chemistry:

- Basic knowledge on different techniques used in analytical chemistry.
- Ability to tackle and solve a problem in analytical chemistry .

- Industrial chemistry:

- Approach and understand major concerns in industrial chemistry.
- Ability to analyse a problem.

- In both:

- Ability to set up an oral presentation (making choices among all the information available).
- Ability to write a report.

Programme Description

- Analytical chemistry:
A short presentation (4h) of the different techniques used in the domain followed by practical. The practical is done in small groups in which the students have to solve a given problem. The problems may be technical (for example) HETP curves, determination of the dead volume of a column...), theoretical (determination of enthalpy of vaporisation by GC or Hammet constants by UV spectroscopy...) or practical (theobromine contents in chocolate, secondary metabolites in citrus fruit ...)
¬ Industrial chemistry:
A course on industrial thermodynamics (8h):

- Basic knowledge on liquid/vapour equilibria.
- Use of a database in thermodynamics for Matlab/Excel.

The aim of this course is to be able to determine the thermos-physic properties of some fluids which will be used in practical.
¬ A personal work on a subject in industrial chemistry:
Study and analysis of a major concern in chemical industry. The subjects of these studies can be rather broad. Examples of recent problems addressed: the production of paper, bio-sourced polymers, antibiotics ....

Knowledge Control Procedures

Oral presentation of the subject in industrial chemistry (25%)
A quiz on the oral presentations (25%)
A written report on the project in analytical chemistry (50%)

Bibliography

D. A. Skoog, D. M. West, F. J. Holler, *Analytical Chemistry*, Boeck University Ed.
D. A. Skoog, F. J. Holler, T. A. Nieman, *Instrumental Analysis Principles*, Boeck University Ed.
F. Rouessac, A. Rouessac, *Chemical Analysis*, Dunod Ed.

Teacher

- Françoise Duprat
- Pascal Denis
-Didier Nuel

Distribution of hours

Total: 50
Magistrates: 12
Directed work: 2
Practical work: 21
Projects: 15

Language(s) used during the course French

Branches

EPC: Design and Design Office

Product Design

Prerequisites: No

Learning Objectives

Design concepts:
-Educate students about

design sketchesDigital makeup:
-Knowledge of the basic features of a mechanical
design software- Characteristics of some common
manufacturing processes-Knowledge of the vocabulary of the few manufacturing and transformation processes discussed
- Educate students about manufacturing methods and means Most

common industrial processesCharacteristics of the additive manufacturing process:
- Training students in additive manufacturing methods and methods, case study and manufacturing

Programme Description

Design sketch (4 sessions 2 h):
- Learning method
- Representing volumes using perspective tools
- Working with the perspective of curved volumes
- Defining object scales, materials and colours
- Draw the design of several products Digital makeup (8 sessions 2 h) :
- Creating mechanical parts: prismatic and surface
- Control parts using plot constraints, parameters and analyses
- Create mechanical parts for manufacturing processes: foundry, plastics, sheet metal
- Create and animate an assembly: Static and Dynamic
- Generate a simple detail layout Characteristics of some manufacturing processes (3 sessions 2 h):
- Session 1: Foundry
- Session 2: Plastics: Injection, extrusion, blowing, rotomoulage.
- Session 3: Sheet Metal

Additive Manufacturing Process (6 sessions 2 h):
- Session 1: General F. A.
- Session 2: Polymer

Technology - Session 3: Metal
Technology - Session 4: Hybrid technology, link with conventional technologies (machining, foundry...)
-Session 5 and 6: Case study and printing

Target generic centrale-specific field-related skills and knowledge

- Control of complexity and systems.
- The Central Engineer masters the complexity of the systems and the problems he encounters.
- Ability to stimulate his imagination, to invent solutions through design studies.
-Ability to realise through 3D representation by integrating the concepts of feasibility.
- Ability to identify interactions between elements (collisions, movement envelope, geometric interference).

Knowledge Control Procedures

CAD software room review: 100%

Bibliography

Online documentation of CATIA software.

Teacher

- Christian Jalain
- Gaël Volpi

Distribution of hours

Total: 52
Magistrates: 18
Directed work: 22
Applied Jobs: 12

Language(s) used during the course French

Branches

EPC: Design and Design Office

Size

Prerequisites: No

Learning Objectives

- Become familiar with the introduction of optimisation concepts in mechanical design processes in engineering
- Apprehend a topology optimisation code used by engineers of design offices, designers or architects and carry out design projects in their entirety

- Learning the modelling technique by Matlab-Simulink
- Realisation of a simulation model from Matlab-Simulink ink
- Use of Matlab-Simulink in the system engineering process

Programme Description

Topology Optimisation:
- Large Classes of Structural Optimisation Problems
- Focus on Topological Optimisation description of the main theoretical concepts
- Application of these concepts on industrial software for topology optimization
- Practice on several case studies
- Evaluation by mini-project

Energy dimensions of a system :
- Introduction of Matlab
- Main functions and basic operations under Matlab
- Use of functions
- Graph under Matlab in 2D and 3D
- Creation and use s-function
- Introduction of the toolboxes (Toobox) of Matlab
- Simulation of dynamic systems with the toolbox Simulink

Directed work: Dimensioning of a wind energy production chain from a specification

Target generic centrale-specific field-related skills and knowledge

Scientific and Technical Innovation
The Central Engineer creates value through scientific and technical innovation:
- Ability to mobilise a scientific/technical culture (transdisciplinarity and/or specialisation)

- Ability to recognise the specific elements of a problem
- Ability to converge towards an acceptable solution (follow-up hypotheses, orders of magnitude...)
- Ability to rapidly deepen a fieldMastery of complexity and Systems.The Central Engineer is in control of the complexity of the systems and the problems it encounters:
- Ability to identify the interactions between elements

Knowledge Control Procedures

Oral (+ Mini Project Report): CC1 50%
Written (Matlab+Simulink): Review 50%

Bibliography

Course transparents Polycopied: Initiation at Matlab.
Introduction to scientific calculation by practice: 12 projects solved with Matlab [work], Dunod, 2005, ISBN: 978-2-10-048709-7.
William J. Palm, *Introduction to MATLAB 6 for engineers* [volume], McGraw-Hill, 2001, ISBN: 978-0-07-234983-2.

Teacher

- Mohamed Boussak
- Jean Marie Rossi

Distribution of hours

Total: 40
Magistrates: 18
Directed work: 22
Applied Jobs: 12

Language(s) used during the course French

Branches

EPC: Design and Design Office

CBE Project

Prerequisites: No

Learning Objectives

- Deployment of a multidisciplinary project, in a team with the submission of a supporting file
- Implementation of a design project that allows the integration of the disciplines seen in the course.
The project can be concluded by the search for subcontractors (implementation estimate), or even the realisation of part of the proposed solution.
-Breakdown of the course in groups of 3 to 4 students.

- Understand demand: translate the need, propose adapted solutions, technically justify and size the chosen solutions, provide numerical models and simulations whenever possible.

Programme Description

- 8 to 10 scheduled sessions supervised by the teacher(s) in rooms equipped with the software taught in the course
-Computer assisted design - CATIA
- Multiphysical modelling of systems with their control - MATLAB SIMULINK
- Topology optimisation - Inspire
- Key points
-Bibliographic search
- Relationship with the customer for a common definition of the need to satisfy
- Justification of the results, understanding and physical size (simulation results)
- Feasibility (choice of processes, integration of existing components)
- Digital model as complete as possible

Target generic centrale-specific field-related skills and knowledge

- Creating value through scientific and technical innovation
-Understanding all the scientific and technical dimensions of a project
- Mastering the complexity of systems
- Rapidly deepening a field
- Developing working methods, organising

Knowledge Control Procedures

Intermediate and final support.
A submission at the conclusion of the project.
CC1 Oral: 10%, CC2 Oral: 30%, CC3 Writes: 60%

Bibliography

Not applicable

Teacher

- Mohamed Boussak
- Jean Marie Rossi
- Christian Jalain

Distribution of hours

Total: 30
Projects: 30

Language(s) used during the course French

PICSEL

Embedded Systems

Prerequisites: No

Learning Objectives

A new generation of systems rich in sensors and massively distributed is emerging, which will have a very important economic and environmental impact. There are many applications involved, including autonomous cars, aerial and submarine drones, factory automation systems, intelligent environments, sensor networks, space probes, etc. In most of these applications, reconfigurable integrated systems are needed that will operate autonomously for years in difficult and uncertain environments, reaching unprecedented levels of skill and robustness. The design and realisation of these intelligent embedded systems requires a software revolution that brings together a variety of computational methods ranging from artificial intelligence, software engineering, operational research and control.

Programme Description

Principles of intelligent embedded systems:
- CPU, energy, memory, I/O and cost constraints
- Sensors and data acquisition
- Security of embedded systems, attack strategies targeting software and hardware parts
Design and realisation:
- Modular design and abstraction
- C
-Language- Parallel digital computing systems (CPU, GPU)
- Programming VHDL training and prototyping by FPGA
- Prototyping with microcontroller, Raspberry, Arduino...
- Electronic interfacing and buses, transmission standards
- Data acquisition and design with Labview / Matlab
TP:- TP programming in C
- TP programming in VHDL with associated CAD tools (ModelSim, Quartus, etc.); configuring FPGA with Altera/Xilinx design-kits-
-TP LabviewMini-projects
- Practical examples of application and configuration of Arduino, Raspberry cards...

Speakers / external speakers :
- IFREMER, YELLOWSCAN, OSEAN, OLEDCOMM
...

Target generic centrale-specific field-related skills and knowledge

This module covers the principles of embedded systems and the methods of designing, prototyping and making such systems. In addition to the physical aspects, the module offers students a set of design tools that are essential for prototyping and the realisation of embedded systems in a wide range of applications.

Knowledge Control Procedures
Continuous monitoring: 60%, Applied Works and Project: 40%

Bibliography
Introduction to real-time embedded systems: Design and Implementation, Dunod 2018
Embedded Real Time Systems: Specification, Design, Implementation and Time Validation, Dunod 2014

Teacher
- Ali Khalighi
- Hassan Akhouayri
-Nicolas Bertal

Distribution of hours
Total: 80
Magistrates: 30
Directed work: 10
Practical work: 20
Applied Jobs: 10

Language(s) used during the course French

PICSEL

Telecom and IoT

Prerequisites: No

Learning Objectives

The engineering of wireless telecommunications and IoT systems is an expertise that enables future graduates to integrate into this growing economic sector, especially with the emergence of massive connected objects and the imminent deployment of future 5G networks. They will have the know-how to implement the technologies of the next generation of networks with high energy and spectral efficiency. They can showcase their knowledge in many emerging applications, particularly those in future smart cities and smart homes. They will also be able to play the role of advisor for setting up new networks and technologies to be chosen to interconnect devices for Internet of Things (IoT) clients.

Programme Description

Bases of digital transmissions:
- Information processing for telecom systems
- Emission techniques (compression, coding, multiplexing, modulation...) and reception (detection, demodulation, decoding...)
- Transmission medium (channel) and associated disturbances
- Transmission protocols
- Multi-user systems
- Ultra-broadband, software radio and smart radio transmissions
- Energy consumption of systems/networks and techniques of "eco-radio"
- Quantum protocols for transmitting information (quantum cryptography, quantum teleportation, "entanglement swapping")

Applications:
- Wireless transmissions: Mobile telephony (including future 5G networks), television broadcasting, local broadband networks (Wi-Fi), extended (WiMAX, LPWAN: LoRa - Sigfox...), and personal (Bluetooth, Zigbee...)
- Sensor networks, smart grids...
- Wired transmissions: ADSL, carrier current...
- Satellite
communications- Fibre optical communications, wireless optics (laser or Free-Space Optics FSO communications, Li-Fi, intelligent lighting...)
- Industrial IoT and IoT for intelligent environments (smart city and smart home, e-health, factories of the future); WebService and Cloud Interface Fog networking...

TP:
- TP Labview, Matlab and Simulink-Matlab: study of a wireless transmission chain.
- TP wireless optical transmission (transmission model)
- TP IoT industrial: use of Smart-building
- TP multi-user systems based on CDMA and OFDM (transmission models)

Speakers / external speakers:
- Nokia Bell-labs, ERCOM, SNEF-Connect, GreenCityZen, Netatmo...

Target generic centrale-specific field-related skills and knowledge

This module provides students with the foundation of telecommunications and a good understanding of communication systems, enabling them to acquire solid skills in digital communications systems, especially wireless. In addition to the traditional systems that have been deployed massively to date, advanced communication systems that are considered to be technology niches, particularly in relation to IoT applications, and the main challenges for the deployment of these systems will be addressed.

Knowledge Control Procedures

Continuous monitoring: 80% TA: 20%

Bibliography

Fundamentals of digital communication, Cambridge University Press, 2008.
Visible light communications: theory and applications, CRC Press, 2017.
LTE and the evolution to 4G Wireless: design and measurement challenges, Agilent Technologies, 2009.
Cellular internet of things: technologies, standards, and performance, Elsevier Academic Press, 2018.

Teacher

- Ali Khalighi
- Hassan Akhouayri
- Nicolas Bertal
- Thomas Durt

Distribution of hours

Total: 80
Magistrates: 40
Directed work: 10
Practical work: 20
Applied Jobs: 10

Language(s) used during the course French

MECA

Experimental methods

Prerequisites: No

Learning Objectives

The objective of this module on experimental methods is twofold:
- On the one hand, to give students an overview of the problems related to metrology in the context of mechanics (i.e. specific measures of stress, speed, temperature, etc.). This is done within the framework of 2 4 hour courses: one centred on measurement techniques, the other on data and signal processing.
- On the other hand, through 3 practical sessions to discover and study, theoretically and experimentally, original physical phenomena: jet instabilities, surface wave propagation, turbulent boundary layer.

- Know the main measuring techniques in mechanics
- Know the main sources of metrological error
- Know how to interpret experiments

Programme Description

- Course 1 and 2
Introduction to Experimental Techniques
- Normatical Aspects of a Measure
- Characteristics and Performance of a Measurement Chain
- Acquisition and Processing of Numeric Data
- Deformation Measures in Solids (Deformation Gauges, Stereocorrelation)
- Measures of stress in fluids (pressure, friction measures)
- Measurement of speed in fluids (sensors) pressure, wire/hot film anemometry, Laser Doppler velocimetry, particle image velocimetry)
- Temperature measurement (for fluids and solids), physical probes (thermocouple, Pt100, etc.), thermography, Laser-induced fluorescence.
-Processing techniques applied to surface wave measurements in a basin:
- Filtering
- Modal decomposition
- Time/frequency analysis
-Practical work
- Study of the instability of Plateau-Rayleigh (formation of drops in a liquid jet)
- Study, in hydraulic channel, of the run-up of a soliton on a vertical wall
- Study of a turbulent boundary layer by anemometry wire

Target generic centrale-specific field-related skills and knowledge

- Experimental measurement problem analysis (C2)
- Determine the *ad hoc* characteristics of the measurement system used (C2)
- Know the main measurement techniques used in mechanics and control their advantages/disadvantages (C2)
- Know the main data processing techniques (C2)

Knowledge Control Procedures
3 TP: 100% (3 workouts per student)

Bibliography
E. Rathakrishnan, *Instrumentation, measurements and experiments in Fluids*, CRC Press, 2007.
A.S. Moris and R. Langari, *Measurement and Instrumentation*, *Second Edition: Theory and Application*, Elsevier, 2015.
Mr. Kutz, *Mechanical engineer's handbook*, vol 2, Wiley, 2015.

Teacher
- Olivier Boiron (ECM)
- Olivier Kimmoun (ECM)
- Cédric Maury (ECM)
- Daniel Mazzoni (ECM)

Distribution of hours
Total: 20
Magistrates: 8
Practical work: 12

Language(s) used during the course French

MECA

Biomechanical

Prerequisites: No

Learning Objectives

- Understanding the complexity of the characteristics and functioning of living environments - Predicting and analysing the mechanical phenomena of the living world to bring new insights from the mechanics on health issues - Know how to identify the key mechanisms and choose the right models according to the problem considered for living environments - Acquire and master certain tools for modelling and characterising living environments

Programme Description

The objectives of the programme will be conceptualised in an introductory speech that will present the educational motivations. Some examples of articulation: biological system/functioning/pathology/modelling/diagnosis & therapy/ will link medical and mechanical context. The medical context will be addressed by a clinician who is familiar with clinical research activities. Courses on the characterisation, modelling of biological tissues and fluids and fluid-structure interactions will be provided by specialised teacher-researchers. They will be declined by explaining their contribution to the articulation examples. As part of a project, students will be offered various scientific articles directly related to the courses to help them understand scientific research. Finally, practical work that will be a practical application of the courses will be proposed.

Target generic centrale-specific field-related skills and knowledge

- Understanding and simplifying a complex problem with biomechanics (C2)
- Know how to propose adapted solutions (C2)
- Know how to structure your work over time (C3)
- Know how to report your work both orally and in writing (C3)

Knowledge Control Procedures

CC1: 10% of MCQs start of each
courseCC2 25%
ATTC refund: 25%
bibliographyDS analysis: 40%

Bibliography

Y. C. Fung, *Mechanical Properties of Living Tissues; Traffic; Motion, Flow, Stress, and Growth, Springer Edition.*
Jay D. Humphrey, *Cardiovascular Solid Mechanics: Cells, Tissues, and Organs*, Springer Edition.

Teacher
- Cécile Baron
- Olivier Boiron
- Carine Guivier-Curien
- Valérie Deplano
- 1 clinician

Distribution of hours
Total: 24
Magistrates: 14
Directed work: 4
Practical work: 6

Language(s) used during the course French

GREEN

Reactor engineering

Prerequisites: No

Learning Objectives

Most processes contain at least one reaction step. The general engineer wishing to pursue his career in the chemical, pharmaceutical or environmental industries must therefore be able to:
- Establish specifications (type and volume of reactor, heat exchange, flow rates, etc.) according to the desired product and the properties of the system
- Evaluate the performance of a process (selectivity, conversion rate) according to the operating
parameters - Identify the key parameters of a process and assess their influence

Programme Description

- Isolated ideal reactors
- Non-isothermal ideal reactors –
- Real-life reactors
- Catalytic reactors

This programme will be addressed in the form of courses, directed works and/or mini-projects. Students may need computer tools (tablet, laptop) during some sessions.

Target generic centrale-specific field-related skills and knowledge

- Ability to solve complex problems
- Ability to collect and sort information
- Ability to mobilise a scientific and technical culture
- Ability to communicate in English and French on subjects concerning discipline

Knowledge Control Procedures

DS1 - Monitored Writing: 50%
CC1 - Report: 50%

Bibliography

The slides of the course are available on Moodle.
The following bibliographic references are available at the Documentation Centre:
H. S. Fogler, *Elements of chemical reaction engineering*.
J. Villermaux, *Chemical reaction engineering: design and operation of reactors.*

Teacher

- Nelson Ibaseta

Distribution of hours

Total: 25
Magistrates: 13
Directed work: 12

Language(s) used during the course French

GREEN

Solid Chain Operations

Prerequisites: No

Learning Objectives

60% of chemicals are marketed in solid form. Similarly, 90% of medicines contain an active ingredient in solid form in their formulation. In addition, there is a growing interest in the applications of crystallisation in water treatment, in a waste recovery approach.
The objective of this EU is therefore to allow a general engineer to:
- Establish a specification (type and volume of crystallizer, heat to exchange, flow rates, etc.) according to the desired product and properties of the system
- Evaluate the performance of a process (size of crystals, crystalline shape, etc.) according to the operating parameters
- Identify the key parameters of an operation and evaluate their influence

Programme Description

Introduction
- Solid Chain
- Characterisation
- Crystal Structure
- Crystal Shape Shape factors
- Size distribution
- Crystallisation
- Thermodynamics
- Solubility
- Phase diagrams
- Kinesitics
- Nuclear
- Growth
- Dimensioning of crystallizers
- Choice of crystallizer

- Types of crystallizers
- Population balance; model MSMPR
-Filtration
- Introduction to solid-fluid separations
- Principles of filtration on support
- Types of filtersDrying
- Principle of drying
- Types of drying

Target generic centrale-specific field-related skills and knowledge

- Ability to solve complex problems
- Ability to collect and sort information
- Ability to communicate in English and French on subjects related to discipline

Knowledge Control Procedures
DS1 - Final Review: 100%

Bibliography
D. W. Green, R.H. Perry (Eds), *Perry's chemical engineers' handbook*.
S. Myerson, *Handbook of Industrial*
CristallizationW. L. McCabe, J. Smith, P. Harriot, *Unit Operations o.f Chemical Engineering*.
J. W.Mullin, *Crystallisation.*
J. D. Seader, *Separation Process Principles*.
H.-H. Tung, E. L. Paul, M. Midler, J.A. McCauley, *Crystallisation of Organic Compounds. An Industrial Perspective.*

Teacher
- Nelson Ibaseta (Centrale Marseille)
- David Baltes (Sanofi)

Distribution of hours
Total: 25
Magistrates: 13
Directed work: 12

Language(s) used during the course French

MECA

Fluid/Structure Interactions

Prerequisites: No

Learning Objectives

- Gain the knowledge necessary to identify situations that could potentially lead to Fluid/Structure couplings and be in a position to propose palliative solutions when possible
- Know the main modes of coupling
- Know how to model, analyse and size a simple FS coupling problem
- Know how to interpret experiences using FS couplings

Programme Description

- Examples of FS couplings in civil engineering, aeronautics/space, energy
- Fluid mechanical and elastodynamic reminders
- Dimensional analysis of FS couplings
- Classification of Fluid/Structure interaction problems
- Structure immersed in a resting fluid - mass added
- Aeroelasticity (aeroelastic coefficients and applications in aeronautics and civil engineering)
- Tuned Liquid Damper (POGO effect)
- Deformable lines (biomechanical and hydraulic applications)
- Introduction to the numerical study of FS couplings

Target generic centrale-specific field-related skills and knowledge

- Ability to model and analyse Fluid/Structure (C2) couplings
- Ability to master the associated dimensioning methods (C2)
- Ability to calculate aerodynamic forces on structures (C2)
- Ability to interpret experiment results (C2)

Knowledge Control Procedures

CC: 2 hr review (70%) - 4 hr TP (30%)

Bibliography

E.H. Dowell, *A modern course in aeroelasticity*, Kluwer acad. publisher, 2004.
C. Carmona, and J.-C. Foucriat, *Wind behaviour of bridges*, Presses of bridges and pavements, 2002.
E. de Langre, *Fluids et solids*, Éditions de l'école polytechnique, 2001.
M. Païs T1&2, Elsevier, 2004.

Teacher
- O. Boiron

Distribution of hours
Total: 24
Magistrates: 16
Practical work: 8
Other

Language(s) used during the course French

CliMaTHs

Statistical Learning

Prerequisites: No

Programme Description
Reminder of useful mathematical tools: Gradient descent method, algorithmic complexity, conditional expectation, to be completed according to the course of the students enrolled in the option. Introduction to Regression and Classification Problems, Tree Methods: regression tree, classification tree, tree forest, boosting method, methods of nearest neighbours in regression and classification Support Vector Machine, neural networks,

Target generic centrale-specific field-related skills and knowledge

Knowledge Control Procedures
Continuous

Teacher
- Thomas Opitz (INRAE, Avignon)
- Jacques Liandrat (ECM)
- Jean Baccou (IRSN)
- Christophe Pouet (ECM)

Distribution of hours
Total: 20
Magistrates: 20
Directed work
Practical work
Applied
Projects
Other

Language(s) used during the course French

CliMaTHs

Extreme Values and Climate

Prerequisites: No

Programme Description
Extreme Value Theory in Dimension 1: Generalised Extreme Value Distributions (GEV), max-stable laws, generalised Pareto law data diagnostic tools: QQ-plot, suitability and uniformity tests; tail index estimate: Hill and Pickands estimators; estimation of rare event characteristics: Extreme quantities, return level, return period extension to dimension d > 1: spatial dependence of maxima.

Target generic centrale-specific field-related skills and knowledge

Knowledge Control Procedures
Continuous

Teacher
- Thomas Opitz (INRAE, Avignon)
- Jacques Liandrat (ECM)
- Jean Baccou (IRSN)
- Christophe Pouet (ECM)

Distribution of hours
Total: 20
Magistrates: 20

Language(s) used during the course French

CliMaTHs

Multi-Agent Modelling

Prerequisites: No

Programme Description
Use of multi-agent models and simulations to show how to consider addressing environmental governance and coordination issues by focusing on economic and policy aspects.

Target generic centrale-specific field-related skills and knowledge

Knowledge Control Procedures
Continuous

Teacher
- Guillaume Chiavassa (ECM)
- Jacques Liandrat (ECM)
- Magali Tournus (ECM)
- Juliette Rouchier (CNRS, Lamsade)
- Emmanuel Prados, Serge Fenet
- Jean-Yves Courton, Peter Sturm (INRIA Grenoble)
- Michael Ghil (ENS Ulm)
- Stephen Spain (AFD)
- Antoine Godin (AFD)

Sustainable development objectives (SDO)

Distribution of hours
Total: 20
Magistrates: 20

Language(s) used during the course French

CliMaTHs

Anthropocene and its future

Prerequisites: No

Programme Description
The aim of this course is to first discover and understand the complexity, scale and urgency of the environmental challenges facing our modern civilisation. We will try to glimpse how intertwined are all the crises that we are facing today and those that are to come.

Knowledge Control Procedures
Continuous

Teacher
-Guillaume Chiavassa (ECM)
- Jacques Liandrat (ECM)
- Magali Tournus (ECM)
- Juliette Rouchier (CNRS, Lamsade)
- Emmanuel Prados
- Serge Fenet
- Jean-Yves Courton
- Peter Sturm (INRIA Grenoble)
- Michael Ghil (ENS Ulm)
- Stephen Spain (AFD)
- Antoine Godin (AFD)

Distribution of hours
Total: 20
Magistrates: 20

Language(s) used during the course French

CliMaTHs

EDP in Biology: Growth, reaction, movement

Prerequisites: No

Programme Description

The objective of this course is to present and mathematically study EDP (Partial Derivation Equations) models, used in population dynamics, called Reaction-Diffusion equations. The term population is to be taken here in an abstract sense: We can write human, animal (mosquitoes, toads), but also cell populations (healthy or cancerous).
We study model behaviours qualitatively, that is, by manipulating the equations, we can predict the evolution of the system. This often comes in addition to a numerical study that consists of solving equations using a numerical schematic implemented on computer. The advantage of a qualitative study over a numerical study is that it avoids the need to calibrate the model, that is, to find the values of the model parameters. Indeed, if parameters (the viscosity of a fluid, molar masses) are often experimentally measurable in physics, in models that intervene in population dynamics, parameters are more abstract (the mortality rate of a population, the rate of invasion of a population of cells). Depending on the model, different scenarios can be predicted: the population can become extinct in a long time, or converge into a stable state. In the event that two populations are present, one may overtake the other, the two may cohabit in a stable manner in long time, or both may annihilate.

Knowledge Control Procedures

Continuous

Teacher

- Guillaume Chiavassa (ECM)
- Jacques Liandrat (ECM)
- Magali Tournus (ECM)
- Juliette Rouchier (CNRS, Lamsade)
- Emmanuel Prados, Serge Fenet
- Jean-Yves Courton
- Peter Sturm (INRIA Grenoble)
- Michael Ghil (ENS Ulm)
- Stephen Spain (AFD)
- Antoine Godin (AFD)

Distribution of hours

Total: 20
Magistrates: 20

Language(s) used during the course French

CliMaTHs

Mathematical Problems in Climate Dynamics

Prerequisites: No

Programme Description

Read I: Observations and planetary flow theory-Geophysical fluid dynamics. Reading II: Atmospheric Low-frequency variability and Long-range forecasting. Reading III: Energy balance models, paleoclimate and 'tipping points'. Reading IV: Nonlinear and stochastic models-random dynamical systems. Read V: Advanced spectral methods-Singular-spectrum analysis et al. Reading VI: The wind-driven ocean circulation.

Teaching team

- Guillaume Chiavassa (ECM)
- Jacques Liandrat (ECM)
- Magali Tournus (ECM)
- Juliette Rouchier (CNRS, Lamsade)
- Emmanuel Prados, Serge Fenet
- Jean-Yves Courton
- Peter Sturm (INRIA Grenoble)
- Michael Ghil (ENS Ulm)
- Stephen Spain (AFD)
- Antoine Godin (AFD)

Distribution of hours

Total: 20
Magistrates: 20

CliMaTHs

Coupling and models: Economy, ecology, society

Prerequisites: No

Learning Objectives

Modelling in the Anthropocene Era: context elements on the interactions between society/economy/finance/environment.
Climate negotiation and integrated climate-economy modelling: Low-carbon transition, a technical-economic paradigm shift that is difficult to model.Financial and climate instabilities, a perfect combination of circumstances?
Case studies of an emerging economy facing climate impacts - north-south dependencies in transition

Knowledge Control Procedures

Continuous

Teacher

- Guillaume Chiavassa (ECM)
- Jacques Liandrat (ECM)
- Magali Tournus (ECM)
- Juliette Rouchier (CNRS, Lamsade)
- Emmanuel Prados, Serge Fenet
- Jean-Yves Courton
- Peter Sturm (INRIA Grenoble)
- Michael Ghil (ENS Ulm)
- Stephen Spain (AFD)
- Antoine Godin (AFD)

Distribution of hours

Total: 20
Magistrates: 20

Language(s) used during the course French

CliMaTHs

Analysis and simulations of road traffic

Prerequisites: No

Programme Description
Presentation of models in road traffic (Follow the Leader, Lighthill-Witham-Richards) with two different approaches: a multi-agent approach and a fluid approach. Traffic control will be addressed for the reduction of particulate emissions (stop and go waves, self-driving cars).

Knowledge Control Procedures
Continuous

Teacher
- Florence Hubert (AMU)
- Magali Tournus (ECM)
- Thierry Goudon (INRIA Nice)
- Jose-Ramon Herrero (Barcelona University)
- Thomas Dubos (Dynamic Meteorology Laboratory, École Polytechnique)

Distribution of hours
Total 20
Magistrates: 20

Language(s) used during the course French

CliMaTHs

High Performance Computing for Weather and Climate

Prerequisites: No

Programme Description

This reading includes geophysical fluid dynamics, hydrodynamic instabilities of vortices and stratified shear flow, geophysical turbulence, numerical methods for general circulation models, idealised applications to terrestrial and planetary circulation. HPC specificities are developed.

Knowledge Control Procedures

Continuous

Teacher

- Florence Hubert (AMU)
- Magali Tournus (ECM)
- Thierry Goudon (INRIA Nice)
- Jose-Ramon Herrero (Barcelona University)
- Thomas Dubos (Dynamic Meteorology Laboratory, École Polytechnique)

Distribution of hours

Total: 20
Magistrates: 20

Language(s) used during the course English

CliMaTHs

Optimisation and control

Prerequisites: No

Programme Description
The aim of this course is to solve a problem of optimisation in finite dimension under constraints, and to master the tools to understand a problem of optimisation in infinite dimension (Lagrange multipliers, gradient methods, stochastic algorithms). Aspects of control theory will be present.

Knowledge Control Procedures
Continuous

Teacher
- Florence Hubert (AMU)
- Magali Tournus (ECM)
- Thierry Goudon (INRIA Nice)
- Jose-Ramon Herrero (Barcelona University)
- Thomas Dubos (Dynamic Meteorology Laboratory, École Polytechnique)

Distribution of hours
Total: 20
Magistrates: 20

Language(s) used during the course French

CliMaTHs

Scientific calculation

Prerequisites: No

Programme Description
Different 1D elementary discretions (finite differences, finite volumes, finite elements) will be studied and compared. Some theoretical properties of some schemas will be studied and implemented in TP.
The discretisation of the finished volumes of the constant speed problem will also be discussed. The stability and convergence properties of these discretions will be digitally and theoretically demonstrated.

Knowledge Control Procedures
Continuous

Teacher
- Florence Hubert (AMU)
- Magali Tournus (ECM), Thierry Goudon (INRIA Nice)
- Jose-Ramon Herrero (Barcelona University)
- Thomas Dubos (Dynamic Meteorology Laboratory, École Polytechnique)

Distribution of hours
Total: 20
Magistrates: 20

Language(s) used during the course French

PICSEL

Founbdations of scientific knowledge

Prerequisites: No

Learning Objectives

This Education Unit aims to provide a foundation for the core of the PICSEL scientific programme (Physics, Waves, Signal). It aims to provide the common ground to take full advantage of the lessons learned.
The EU is structured around 4 parts (8 h each):
- Signal processing. Objectives: Learn and master advanced methods of signal and image processing and analysis - Introduction to GPS technology. Objectives: show the role of modern physics (quantum physics, relativities) in the design and operation of GPS, especially at the level of on-board atomic clocks - Reminder on the theory of physical systems. Objectives: Provide the Engineer with the methodological basis for the analysis and probability tools for the study of physical systems - Wave Reminders. Objective: master the bases of electromagnetism in dielectric, non-magnetic, homogeneous linear and isotropic media

Programme Description

-
Signal processingThis course allows you to know and master advanced methods of processing and analysing signals and images, and their implementation in real contexts. It also provides the necessary knowledge to propose innovative solutions for the analysis of signals and images in systems engineering.
- Introduction to GPSR technologyCall on quantum mechanics postulates and the transformation of Lorentz (1A course), plus principle of operation of a GPS, Hamiltonian of material-light interaction, transitions between quantum levels in an e-m field resonant, Ramsey interferometer and relativistic corrections for GPS.
- Theory of physical systemsReminder on the distributions and the theory of the linear response, the analysis of the fluctuations of the main physical processes and the description of the main tasks of signal processing.
- Waves:
- Maxwell equations in vacuum and in media, applications to non-magnetic LHI media: local equations, integral equations, load conservation, wave equations, structure equations, electromagnetic energy and transient relations.
- Progressive homogeneous monochromatic waves and polarisation (+ polarizer).
- Reflection and reflection: Demonstration of Descartes' laws, calculations of Fresnel coefficients (field and energy) and evanescent waves.
- Phase blades

Target generic centrale-specific field-related skills and knowledge

- Master the main concepts of applied mathematics and basic physics for statistical optics and/or signal processing - Link theory, experience and technology in the case of GPS, understanding by this example the crucial role of interdisciplinarity, as well as the importance of modern physics up to the latest technological developments

Knowledge Control Procedures

Continuous monitoring: 25 % for each subpart

Bibliography

Pérez, *Electromagnetism: Foundations and Applications.*
Ph. Refregier, *Signal Theory*, Masson.
CJ Foot *Atomic Physics*.

Teacher

-Salah Bourennane
- Thomas Durt
- Laurent Gallais
- Philippe Réfréger
-Nicolas Sandeau

Distribution of hours

Total: 32
Magistrates: 32

Language(s) used during the course French

PICSEL

Complex Systems Management

Prerequisites: No

Learning Objectives

This teaching unit aims to illustrate and provide examples of the notions of project management covered in 1A 2A through interventions from a professional with experience in the scientific themes related to PICSEL.
This course relates to the management of space projects and is delivered by Rodolphe Krawznyk (THALES).
Rodolphe Krawczyk has been working in the space industry for 40 years. He has managed several projects for the European Space Agency, and for 10 years has been the director of the optical instruments for satellites pre-projects department. He is a member of several commissions to improve internal processes in his company (management and risk management).

Programme Description

The course is broken down into 3 parts in which a group of notions related to project management will be addressed in the context of space exploration, and illustrated by real-life cases based on the speaker's experience.
1st part:
– Some definitions
– The specificities of space
– The professions involved
- Pragmatic difficulties
- Documentation
- Development
2nd part:
– Example: optical instrumentation
– Means available for testing
- Examples of completed projects
- Report on experiments and lessons learned
– Points to remember
– Conclusions
3rd part:
– Visit of the Thales Alenia Space installation (Cannes)

Target generic centrale-specific field-related skills and knowledge

- C2: mastery of the complexity of systems and resolution of complex problems characterised by strong interactions across disciplines, professions and human factors.
- C3: conducting and leading programs taking into account the scientific, technical, economic, financial and human aspects.
R

Knowledge Control Procedures

Continuous monitoring: 100%

Bibliography
Course Support

Teacher
-Rodolphe Krawczyk
-Laurent Gallais

Distribution of hours
Total: 16
Magistrates: 16

Language(s) used during the course French

Branches

R&D: Research & Development

R&D Project

Prerequisites
EU S9 R&D: OMRD (research organisation and methodology) and OCVR (organisations, contracts, research value)

Learning Objectives
- Insertion into a research team
-Taking over part of an elaborate research work
- Knowledge of the environment of a laboratory This type of project aims to integrate students in an ongoing action in one of the laboratories, with the aim of being immersed in a structured R&D action, in order to see some the organisation, the financing mechanisms, the constraints, the objectives ... and to make the link with the concepts discussed in the EU OMRD and OCVR courses.

It may be requested in the context of this project to set up a scientific activity: round tables, scientific papers, feedback...

Programme Description
For the experimental sciences, the stay in the laboratory can be an apprenticeship (supplement of the ECM training) of the experimental methodology of the 3A and/or master option theme. For others it may be more an immersion in the research themes of a laboratory or team of their choice in connection with their 3A and/or master.
Students who are more interested in development and research in industry will be able to choose topics that allow them to see the evolution of a topic until it is valued in the context of laboratory/company collaboration.Students are expected to take advantage of this period in the laboratory to exchange ideas with the various players in the research in order to get a clear understanding of the different professions and functions encountered in the structure.

Knowledge Control Procedures
Assessment Form completed by the laboratory guardian
Project Report

Teacher
-C. Fossati

Distribution of hours
Total: 60
Projects: 60

Language(s) used during the course French

Branches

Research & Development

Organisation, contracts and research valuation

Prerequisites: No

Learning Objectives
-Present the different types of collaborations and contracts that the future engineer may have to mount and manage. To give ideas about how to use the results that are associated with it.
- To help the student to know how to identify valuable results
- To know the different possibilities of using and transferring the results of research
- To know different types of contracts
- To know what are the main steps to set up a collaborative research project

Programme Description
The aim of this course is to show, by presenting professional experiences and concrete examples, the main aspects:

- From creativity to scientific innovation
- Introducing innovation and creativity in the context of scientific and industrial research, raising awareness of the non-technical issues of scientific innovation
- From scientific innovation to valorisation or transfer of technology
The aim of this course is to see in general how to evaluate and value research results (publication, patent, marketing, start-up...) and/or transfer of technology from a laboratory to a company with the related concepts of intellectual property protection.

Research Contracts
- Different types of contracts and collaborative works: Know the different types of contracts and collaborative work that can be established between research teams, laboratories, companies...
- Contracts in the European area: Know how research contracts operate in the European area from the study of a practical case

Knowledge Control Procedures
Continuous

Teacher
- C. Fossati (ECM)
-J.C Coilard (Centrale innovation)
-P. Spiga (Protisvalor)
- Outdoor speakers

Distribution of hours

Total: 24
Magistrates: 24

Language(s) used during the course French

Branches

Research & Development

Tools and Methods for R&D and Innovation

Prerequisites: No

Learning Objectives
Provide students with basic skills and methodology tools in the field of R&D, as well as knowledge of the relevant fields and trades. The concepts discussed may be useful if the student is destined for a first job in R&D of course, but also in the context of any possible collaboration for an engineer with departments or laboratories of R&D.

Programme Description
- Concepts of methodology for conducting research
- Presentation of the various possibilities for research (academic, R&D department of large companies, SME...)
- Link between research and innovation/creativity/industrial property
- Knowledge management concepts for research
- Reflection on epistemology for research...

All these concepts are illustrated by the personal experience of the various stakeholders involved.

Knowledge Control Procedures
Continuous

Teacher
- C. Fossati (ECM)
- S. Bourennane (ECM)
- O. Provitina (CEA)
- External Speakers

Distribution of hours
Total: 24
Magistrates: 24

Language(s) used during the course French

Branches

PRL: Production & Logistics

PRL Project

Prerequisites:

Business
ManagementIndustrial Logistics

Learning Objectives

- Make the students involved in their training (self-learning and team organisation) around a given or chosen subject.
- Provide the students with a concrete framework to carry out a project that allows them to better understand the reality of the world of industrial organisation and logistics.
-Encourage the students to refine their professional project by crossing their desires, their skills and concrete cases in company.
- Develop their aptitude design, plan and realise a project, work in teams, under constraints and communicate its results.

Programme Description

This EU includes:
- Case Study #1: analyse a concrete organisational problem in a company. Propose team improvements.

- Case Study #2: analyse a concrete supply chain problem in an enterprise. Propose team improvements.

- Lean
Management SimulationIt allows us to approach all the concepts of Lean Management. Participants take on roles on the board of a company that has decided to improve its operational performance. The project progresses in an orderly manner:
- draw on posters the detailed mapping of the main processes
- identify the various Mudas (waste) and the non-value added
- calculate the performance indicators
- investigate the causes of non-value added
- propose improvement actions
- assess the risks
- measure the gains
The topics covered cover the main functions of the company: procurement, production, sales, distribution, new product design, finance, human resources.

Target generic centrale-specific field-related skills and knowledge

- Programme direction: Technical aspects (needs analysis, design, planning, and project monitoring) with organisational aspects (stakeholders, organisation, communication)
- Human management: all aspects of team management (role of project manager, members, and coordination of actors)

Knowledge Control Procedures

CC1: 100%

Bibliography

Case studies.
Lean Management simulation, CIPE.

Teacher

- Cécile Loubet
- Florian Magnani

Sustainable development objectives (SDO)

8-Access to decent jobs
12-Responsible consumption and production

Distribution of hours

Total: 30
Projects: 30

Language(s) used during the course French

Branches

PRL: Production & Logistics

Industrial logistics

Prerequisites:

Business management
Knowledge of the company and its organisation

Learning Objectives

-Understand the current missions and challenges of logistics and production players, the difficulties they may encounter and the keys to manage them
- Understand the concrete applications in the company of strategic declinations and the establishment of a management of the Supply Chain
- Develop a managerial analysis in the face of a problem of the Supply Chain
- Know the theories of visual management and observation of production situations (analysing constraints through practice)

Programme Description

This EU includes:
- a module on the management of the Supply Chain:
- Courses and sharing of experiences on strategies and management of the logistics and the Supply Chain, analysis of concrete cases through case studies
- Upstream and downstream flow optimisation (control and reduction of lead time, planning, push/pull flows, Kaizen, methodologies, human dimension) around a serious game A module on observational and visual management methodologies:
- Courses, experience sharing with a PSA professional, face-to-face
- An approach to the concepts of the future industry

Target generic centrale-specific field-related skills and knowledge

- Scientific and technical innovation: Identification of Supply Chain innovations, their usefulness, the points of vigilance and choice of innovations for optimisation
- Control of complexity and systems: complexity resulting from multi-stakeholder industrial systems, identification of issues and commitment to their resolutions
- Human management: all aspects of team management (role of logistics players, conflict management and coordination of actors)
- Strategic vision: definition of a transverse strategy and placing under control its operational decline

Knowledge Control Procedures

Supply Chain Management DS1, 2h: 40%
Visual management and CC1 observations: 30 %
Serious game of Supply Chain CC2: 30%

Bibliography

Course
copiesChristopher, M. (2016), *Logistics and supply chain management: creating value-adding networks*, FT Publishing. *International Prentice Hall*, 5th edition.
Chapman, S. N., Tony Arnold, J. R., Gatewood, A. K. and Clive, L. M. (2016,) *Introduction to Materials Management*, Pearson, 8th edition.

Teacher

- Florian Magnani
-Cécile Loubet

Sustainable development objectives (SDO)

8-Access to decent jobs
12-Responsible consumption and production

Distribution of hours

Total: 41
Magistrates: 16
Directed work: 9
Practical work: 16

Language(s) used during the course French and English

Branches

PRL: Production & Logistics

Operations Management

Prerequisites:

Management control
Project managementKnowledge of
the company and its organisation

Learning Objectives

- Understand the stakes, logics and basic concepts of operations, production and flow management - Practically address the mechanisms and constraints of an ERP (Enterprise Resource Planning)
- Master the methods and tools necessary for the analysis, piloting and continuous improvement of any logistics or production system - Understand the main principles of Lean Management
- Familiarise yourself with the fields essential that revolve around the production that are: Quality and safety management at the workplace and risk prevention

Programme Description

This EU includes:

- A module on industrial organisation:
- The various functions within the company and the technical data defined therein.
- The establishment of the operations-production system (location, layout, determination of capacity, management of facilities).
- Inventory and supply management (concepts of cost and economic quantity).
- MRP, Management Resource Planning (master production programme, calculation of requirements, milestone, sequencing).
- Global approaches (Just in time, Lean Management, OPT, Kanban, 6, 5 S...).

- A module on quality control:
- Statistical data processing, statistical process control, efficiency curves and sampling plan.

- An module on ERP:
Using software (ERP Prelude), address the various items:
- articles
- management of bills
- workstations and manufacturing ranges
- storage and inventory transactions
- customer orders
- net requirements calculation
- processing of purchases
- schedulations
- launch and manufacturing follow-up▪cost calculation

A module on operational excellence:
- Introduction to Lean Management (variabilities, waste, autoquality, standards...).
- Optimisation of technical resources (TRS, flows, batch size, SMED. ...).
These concepts are discussed in the context of the layouts at the Dyneo factory-school.

Target generic centrale-specific field-related skills and knowledge

- Scientific and technical innovation: Identification of production innovations, their usefulness, the points of vigilance and choice of innovations for optimisation
- Control of complexity and systems: complexity stemming from multi-stakeholder industrial systems, identification of issues and commitment to their human resolutions
-Management: all aspects of team management (role of production actors, conflict management and coordination of actors)Strategic
Vision: define a localised strategy and subordinate its operational decline

Knowledge Control Procedures

Industrial organisation DS1 2h: 40%DS2 1:30
Quality Control: 20%
ERP CC1: 20 %
CC2 School Factory: 20%

Bibliography

Course copies.
ERP e-Prelude software.
Dyneo factory (ENSAM - Aix-en-Provence).

Teacher

- Cécile Loubet
- Florian Magnani

Sustainable development objectives (SDO)

8-Access to decent jobs
12-Responsible consumption and production

Distribution of hours

Total: 39
Magistrates: 11
Directed work: 12
Practical work: 16

Language(s) used during the course French

DIGITAL

Machine learning

Prerequisites

Common Trunk CoursePython
Programming

Learning Objectives

- Understanding the general principles of machine
learning - Knowing in which situations to use machine learning
- Knowing a panorama of data analysis and machine learning methods
- Analysing the relevance of learning methods to a given
problem - Know how to apply machine learning methods to classic supervised and unsupervised learning problems

Programme Description

The option is divided into several modules that address the different facets of the data scientist's job:
- Data Munging and Data Analysis: data manipulation and analysis.
- Machine Learning and Data: Overview of Machine Learning Methods for Supervised and Unsupervised Learning
- Deep Learning and Neurone Networks: overview of modern neural architectures and research in the field
- Digital optimisation: review of optimisation techniques on which learning algorithms are based (gradient descent, EM algorithm, etc.)
- Distributed calculation: compute technologies distributed on massive data: Map-reduce Hadoop, etc.
An important part of the course is carried out on python machine and focuses on the implementation and experimentation with dedicated packages (pandas, scikit-learn, keras, tensorflow).

Target generic centrale-specific field-related skills and knowledge

This option is an introduction to the field of machine learning, the aim of which is to train data scientists by providing the necessary bases to participate in a Kaggle-type competition (www.kaggle.com).
This module contributes to a broad vision of the scientific and technological issues in the field of digital technology.

Knowledge Control Procedures

Project rendering in all modules
Terminal examination for modules "Machine Learning and Data Science" and "Deep Learning and Neurone Networks" which are shared with the IAAA Master (Artificial Intelligence and Automatic Learning)

Bibliography

Christopher M. Bishop, *Pattern Recognition and Machine Learning*,
https://www.microsoft.com/en-us/research/people/cmbishop/prml-book/

Ian Goodfellow and Yoshua Bengio and Aaron Courville, *Deep Learning*, MIT Press, 2016, https://www.deeplearningbook.org/

Teacher

- Thierry Artières (ECM)
- Hachem Kadri (AMU)
- Thomas Peel (Euranova)
- Muriel Roche (ECM)
- Ronan Sicre (ECM)

Distribution of hours

Total: 100
Magistrates: 90
Directed work: 10

Language(s) used during the course French

PICSEL

Mathematical and computational modelling

Prerequisites: No

Learning Objectives
Provide an introduction to theoretical and computer modelling of light-based devices across a wide range of applications. Students will familiarise themselves with the modelling tools widely used in optics and photonics, but will also understand the underlying physics of the modelled system and the operating principles and approximations inherent in these common simulation tools. Students will also explore the application of many of these techniques in other physical contexts such as acoustics or quantum mechanics.

Programme Description
The course will consist of four modules:

- Module 1: Theoretical and computer models for
light-based devicesThis module will provide an overview of the mathematical and physical principles behind several wave field modelling techniques, including the development of simple numerical implementations. The goal is that these implementations clarify the operating principles of the programmes used in the following modules.

- Module 2: Modelling of guided electromagnetic waves using
FimmwaveModelling of guided modes in fibres and integrated optics, with some applications in hyperfrequency.

- Module 3: Modelling of photonic devices using COMSOL
MultiphysicsSolving complex problems and interpreting phenomena in photonics using COMSOL Multiphysics, which is based on solving the equations with physical partial derivatives using the finite element method.

- Module 4: Modelling of quantum systems using
MATLABusing variational and modal methods to simulate quantum phenomena, using MATLAB.

Target generic centrale-specific field-related skills and knowledge
- C1: Scientific and technical innovation
Having a deep knowledge of physical phenomena is essential for proposing new applications. Similarly, understanding analogies between different fields provides inspiration for importing ideas from one context to another.

- C2: Control complexity and systems
The course will focus on the intersection of optics with a range of other disciplines such as telecommunications and metrology.

Knowledge Control Procedures
5 CC, 2 for Module 1, 1 for each other Module: 20% each.

Bibliography
Notes provided by the instructors, as well as documentation of the various packages used.

Teacher
- Miguel A. Alonso
- Laurent Gallais-During
- Jean Bitterbiere
- Thomas Durt

Sustainable development objectives (SDO)
4-Access to quality education
7-Use of renewable energy
11-Sustainable cities and communities
13-Combating climate change

Distribution of hours
Total: 80
Magistrates: 20
Directed work: 60

Language(s) used during the course French and English

GREEN

Process Design

Prerequisites: No

Learning Objectives
Being able to design a process:

- Knowing/choosing/defining unit operations
- Determining operatingconditions
- Establishing material and energy balances
- Adapting the process to the requirements of safety and environmental risk
- Be able to read/draw a process diagram
- Know the standard standards applicable to process engineering
- Know the basics of CAD-CAD
- Be able to transpose an industrial process on a simulator
- Know the main characteristics of unit operations
- Know how to choose models (thermodynamics, kinetics)

Programme Description
To allow students, through a concrete case, to approach the various aspects related to the design of an industrial process in the field of the chemical, petrochemical or biochemical industry. This involves step-by-step process design development and validation.

Target generic centrale-specific field-related skills and knowledge
- Ability to collect and analyse information with logic and method

- Ability to understand and formulate the problem (hypotheses, orders of magnitude, etc.)

- Ability to understand all the scientific and technical dimensions of a project

- Ability to take into account societal, legal, financial, economic, regulatory issues (see complete competency sheet)

Knowledge Control Procedures
The evaluation is based on group C/renderings (50% of the score) and an individual analysis at a 4-hour session (50%). The step-by-step cut is given as an indication:
Roadmap: 2.5%
Process Overview: 5% Cross-
evaluation of PFD schemes: 10%
Process Flow Diagram - Schema Delivery: 10%
Process simulation: 22.5%
Reports of expertise: 50%

Bibliography

Perry's, *Chemical Engineering Handbook*.
Kirk and Othmer, Encyclopaedia of Chemical Technology.
J. Bevan, Ott and Juliana Boerio-Goates, *Chemical thermodynamics*, vol. 1 and 2.
Harry Silla, Chemical process
engineering R.K. Sinnott, Chemical Engineering Design

Teacher

- Pascal Denis

Distribution of hours

Total: 25
Magistrates: 4
Directed work: 21

Language(s) used during the course French

GREEN

From Resource to Product: practice

Prerequisites: No

Learning Objectives

- Know and apply good laboratory
practices- Use basic materials of experimentation in GP/chemistry
- Use basic materials of analysis in GP/chemistry
- Be able to implement an experimental protocol and/or an operating
procedure - Analyse and exploit results of experience
- Write a scientific report and technical

Programme Description

- Address the main unit operations (three 7 h sessions)

- Implement the synthesis and analysis of specific compounds (three 8 h sessions)

N.B. The effective list of TPs may vary from year to year and adapt to the size of the workforce and the material availability.

A training on the calculation of thermophysical properties used in GP TP with the Simulis Thermodynamics® library will be carried out in progress/TD.

- Mode of operation
Students are usually divided into pairs. The TP session is 7:00 AM (GP) or 8:00 AM (chemistry), with an intermediate break depending on the state of progress of each experience.

- Before the session:

An evaluated preparation will be requested for each TP and given a few days before the session. This allows students to take the experience into their own hands and become active during it.

- During the experiment:

Students will be required to complete an individual laboratory workbook of experiments, which will be provided to them to record all information necessary for the understanding of the experience, its implementation and its exploitation. Particular care will be given to analyses and methods of analysis, compliance with safety rules, control of the equipment and materials available.

- After the experiment:

A scientific and technical report (GP) or a report (chemistry) will be written and transmitted to the teachers in electronic version. The delivery time will be set in the TP copy.

Knowledge Control Procedures

Each TP is subject to three separate evaluations:

- Preparatory work (PM: 20%/chemistry: 20%)
- In-session work and behaviour (GP: 20%/chemistry: 50%)
- Experience Report (PM: 60%/chemistry: 30%

Bibliography

Perry RH, Green DW, *Perry's Chemical Engineers's Handbook*, 8th Edition, McGraw-Hill, 2008.
Haynes WM, *CRC Handbook of Chemistry and Physics*, 96th Edition, CRC Press, 2015:2677.

A specific bibliography is provided in the copy for each TP.

Teacher

- Pascal Denis
- Damien Hérault

Distribution of hours

Total: 50
Magistrates: 2
Directed work: 3
Practical work: 45

Language(s) used during the course French

DIGITAL

Management by Information Systems

Prerequisites

SHS
Eco-Management (organisation and operation of the company)

Learning Objectives

- To understand the main characteristics of digitalisation (use orientation, data centrality) and the opportunities it offers, in terms of value creation, reconfiguration of work practices, transformation of organisational models, emergence of new skills and trades.
-Know the theoretical fundamentals in information systems management (MSI).
- Mobilise the fundamentals in MSI to design an information system based on an organisational diagnostic approach and integrate it into the operational variation of an organisation's strategic directions (definition of strategy, forward-looking dashboards, indicators).
-Know the fundamentals of Change Management and mobilise them to understand a situation of change and formulate recommendations (map impacts, identify targets, accompany desired and induced changes to ensure the appropriation of digital transformation projects and the capitalisation of knowledge and skills).

Programme Description

This EU has three components.

- The module "Digital Transformation of Organisations" (TDO) is presented as a participatory workshop to clarify what digitalisation covers and to develop a deeper collective knowledge of organisational transformations, changes in work practices and employment issues associated with this process.

- The module "Information and management systems" (SIM) presents the fundamentals in information systems management. It engages case studies to understand the role, impact and challenges of information systems in managing a business and optimising business processes in relation to the business strategy.

- The "Conducting Change" (CdC) module combines theoretical and practical approaches to inform policy issues and operational modalities of change support. A specific section is devoted to Knowledge Management.

Target generic centrale-specific field-related skills and knowledge

- C3: Design projects for digital transformation. Adapt steering methods to the nature of the projects and the teams implementing them (agile methods, waterfall...).
- C4: Mobilise, converge actors and support digital transformation by being clear-sighted about opportunities and barriers for the organisation and individuals.
- C5: Integrate transformation processes and information systems into the organisation's strategy, culture and values.

Knowledge Control Procedures

100% DC with details:
- 40% for TDO
- 40% for SIM
- 20% for CDC

Bibliography

Aurélie Dudézert, *La transformation digitale des entreprises*, La Découverte, Collection Repères, 2018.
Marie Benedetto-Meyer, Anca Boboc, *Sociologie du numérique au travail*, Colin, 2021.
Reix, Fallery, Kalika, Rowe, *Information Systems and Management* Vuibert, 2016.

Teacher

-Laetitia Piet (responsible)
- Catherine Boissonnet
- Amandine Pascal
- Isabelle Vasserot
- Nicolas Ciron
- Rémi Denoix

Sustainable development objectives (SDO)

8-Access to decent jobs

Distribution of hours

Total: 100
Magistrates: 65
Directed work: 35

Language(s) used during the course French and English

CliMaTHs

Rebuilding Data

Prerequisites
Applied Mathematics courses of engineering level 2a

Learning Objectives

Programme Description
Data reconstruction in spatial statistics, Kriegtrapling, nucleus methods, multiscale approximation, subdivision patterns, ondelettes.
Applications in risk management and pollutant monitoring.

Knowledge Control Procedures
Project

Bibliography
Course notes.

Teacher
- J. Baccou (IRSN)
- J. Liandrat (ECM)

Distribution of hours
Total: 32
Magistrates: 12
Directed work: 12
Practical work: 8

Language(s) used during the course French

Branches

AUC: Audit & Consulting

AUC Project

Prerequisites: No

Learning Objectives
Companies, like any living system, regularly face development, organisational and strategic problems. The consultant assists business leaders and decision makers in their financial, strategic, management and organisational decisions. The consultancy business involves a wide range of activities, from diagnosis to solutions implementation.The Audit and Consulting training offers students a global vision of the consulting profession. The course enables students to discover the basic missions of the profession, define their professional project, acquire and complete the skills required to approach their profession, develop their potential as a manager, accelerate their employability.

Programme Description
Completion of a project on behalf of a "client" (company):
- Analysis of an organisation
- Financial audit of an enterprise
- Business Assessment
- Policy diagnostics
- Market research
- Analysis of the financial crisis
- Webmarketing

Knowledge Control Procedures
Project Support + Report

Teacher
- Nicolas Clootens
- External speakers

Sustainable development objectives (SDO)
4-Access to quality education
8-Access to decent jobs
17-Partnerships for the achievement of objectives

Distribution of hours
Total: 28

Language(s) used during the course French

Branches

AUC: Audit & Consulting

Audit

Prerequisites: No

Learning Objectives
Companies, like any living system, regularly face development, organisational and strategic problems. The consultant assists business leaders and decision makers in their financial, strategic, management and organisational decisions. The consultant's job involves a wide range of activities, from diagnosis to implementation of solutions.

The Audit and Consulting training provides students with a global vision of the consulting profession. The course enables students to:
- discover the basic tasks of the trade;
-define their professional project;
-acquire and complete the skills required to enter their profession;
- to develop its managerial potential;
- to accelerate its employability.

Programme Description
- Finance: Actuarial Calculation - Discounted Cash Flow - Benchmarking - Actual Options - Financial Audit: Financial Audit - Corporate Risk - International Accounting Standards - Legislative Framework (Financial Security Law, SOX)
- Organisational Audit: Audit - Organisation - Information System - Study, Approach - Management and Management

Knowledge Control Procedures
CC during the courses evaluated + Projects

Bibliography
Will be communicated by stakeholders.

Teacher
External stakeholders

Sustainable development objectives (SDO)
4-Access to quality education
8-Access to decent jobs
17-Partnerships for the achievement of objectives

Distribution of hours
Total: 40

Language(s) used during the course French

Branches

AUC: Audit & Consulting

Council

Prerequisites: No

Learning Objectives

Companies, like any living system, regularly face development, organisational and strategic problems. The consultant assists business leaders and decision makers in their financial, strategic, management and organisational decisions. The consultancy business involves a wide range of activities, from diagnosis to solutions.
The Audit and Consulting training provides students with a global vision of the consulting business. The course enables students to:
- discover the basic tasks of the profession;
- define their professional project;
- acquire and complete the skills required to approach their profession;
- develop their managerial potential;
- accelerate their employability.

Programme Description

- Marketing: Marketing, role, functions, methods - Market studies - Marketing plan - Marketing mix
-Corporate strategy: Business plan - Segmentation - Differentiation - Business portfolio - Process management (organised on the serious game format)
-Consultant trade: Conferences - Professional testimonials: career, tools, methods, and challenges

Knowledge Control Procedures

CC during the courses evaluated and projects

Teacher

- External stakeholders

Sustainable development objectives (SDO)

4-Access to quality education
8-Access to decent jobs
17-Partnerships for the achievement of objectives

Distribution of hours

Total: 42

Language(s) used during the course French

GREEN

Gas treatment and Intensification

Prerequisites:
1A and 2A GP Chemistry Lessons

Learning Objectives
The EU concerns the treatment of polluted gas phases. It is a question of acquiring knowledge of the main pollutants present in the gaseous phase and of the different treatment methods most commonly used. Therefore, it is important to acquire expertise on the choice of the most appropriate process in terms of efficiency and cost.

In detail, the EU includes the following parts:
- The main pollutants in the gas phase and their impact on the environment and health
- The main treatment processes
- Focus on dust removal
- Focus on adsorption
- Focus on gas permeation
- Intrusion process tensification

Programme Description
The EU begins by presenting the main pollutants encountered in gaseous effluents while presenting the environmental and health issues that these emissions pose. Next, a presentation of the main treatment processes is made from the point of view of the principle of the treatment involved and the field of application. Special focus will be on the following unit operations: dedusting, adsorption and gaseous permeation.
The EU will conclude with a project that will uncover the challenges associated with intensifying processes that involve developing more efficient and less expensive processes.

Target generic centrale-specific field-related skills and knowledge
- C1: Scientific and
technical innovationDevelopment of new processes that are more economical, and/or more efficient, based on a detailed knowledge of the basic principles.
- C2: Control of Complexity and Systems
Better management of the effluent production/treatment chain with the aim of getting as close as possible to the objectives of sustainable development and, where possible, effluent recovery (circular economy process).

Knowledge Control Procedures
DS - Written exam 2h: 75%
CC - Intensification Project: 25%

Bibliography
Numerous articles in the journal Engineering.

Teacher

-P. Guichardon
- N. Ibaseta (ECM)

Sustainable development objectives (SDO)

11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 25
Magistrates: 12
Directed work: 6
Projects: 7

Language(s) used during the course French

GREEN

Mix, rheology and cosmetics

Prerequisites:

1A and 2A Chemistry-GP Courses (Balance Sheets and Transfer of Material)1A Mechanical Courses (Fluid Mechanics and Continuous Mechanics)

Learning Objectives

The EU is to familiarise students with the diversity of fluid behaviour and its impact on cosmetic processes and formulation. The aim is to enable students to understand and determine the key elements of agitation and mixing for Newtonian and complex fluids.
In detail, the EU comprises the following parts:
- Development and physico-chemistry of the formulation of cosmetic products- Formulating strategies: notions of cosmetic forms (classification of emulsions, gelatinised forms, microencapsulation)
- Concept of complex fluid: examples (liquid crystals, molten or solution polymers...), multi-scale problem of the description of complex fluids - viscous behaviour: observation/manifestations, structural interpretation (polymers), linear viscoelasticity, non-linear
- Use of rheology in the analysis and development of cosmetic products
- Implementation of the process
- The techniques of agitation, elements of choice of a motive of agitation
- Dimensional analysis
- Hydrodynamics of an agitated reactor
- Macromelange and micromelange
- Process and rheology

Programme Description

The EU begins with a presentation of the formulation strategies in cosmetics where the forms handled are varied: emulsions, gels, capsules... The products used are viscous and often exhibit non-Newtonian flow behaviour. A detailed knowledge component of fluid rheology is presented. The last part deals with stirring and mixing. We will begin to describe the elements of choice of the agitator to go all the way to the full size of the agitated reactor. The Newtonian fluid case is enriched with the one with more complex rheological behaviour.

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and Technical InnovationDevelopment of new, more efficient and/or more efficient processes for the development of innovative products
- C2: Control of complexity and systems
Better management of effects coupled between rheology, process and product use properties

Knowledge Control Procedures

DS - Written exam 2h: 100%

Bibliography
Numerous articles in the journal *Engineering.*

Teacher
- Pierrette Guichardon
- Marc Jaeger (ECM)
- Michel Grisel (UFR Sciences et Techniques, Le Havre)

Sustainable development objectives (SDO)
12-Responsible consumption and production

Distribution of hours
Total: 25
Magistrates: 12
Directed work: 13

Language(s) used during the course French

DIGITAL

DIGITAL-e Project

Prerequisites: No

Learning Objectives
The realisation and management of Agiles projects involves placing the client at the centre of the process.

Programme Description
- Call to Topics
- Presentation of the subjects
- Choice of subjects
- Realisation of the subjects
- Presentation

Target generic centrale-specific field-related skills and knowledge
Concerns related of course to the digital-e themes.
Real motivation and availability to work in close partnership with you.

Knowledge Control Procedures

JobOverviewReport

Sustainable development objectives (SDO)
5-Gender equality
9-Building Resilient Infrastructure
10-Reducing Inequality
16-Justice and peace
17-Partnerships for the achievement of objectives

Distribution of hours
Total: 100
Projects: 100

Language(s) used during the course French and English

DIGITAL

Data Analysis

Prerequisites:
Common Trunk Course

Learning Objectives
Interested in data science and in particular data processing, analysis and understanding. Moreover, you should not have anything against a little theory or writing lines of code if it helps solve a concrete problem.

Programme Description
This EU has three parts (analysis, business application and visualisation):

Part analyses:
- dataframes: use of panda software for data science
-methods of data partitioning (k-means, hierarchies)
- factor method for data analysis (principal component analysis, regressions...)
- behavioural analytics

Business applications:
- management and HR
- public policy
-manipulation of real and massive data sets

Data visualisation part:
- cartographic data
- which graphs for which data?
- my data on the web

Target generic centrale-specific field-related skills and knowledge
Some recent work presents the data as the "new black gold" of the twenty-first century. On the one hand, big data is characterised by the volume, variety and velocity of data, indicating the increasing availability of data, the capture of which is facilitated to the point of spreading to all areas of social and individual life. Human experience, social relationships, emotions themselves can now be turned into data. On the other hand, under the growing influence of behavioural sciences, the exploitation and valorisation of data make it possible to develop concrete solutions in various fields (marketing, human resources, business intelligence, health, economic development...).

Knowledge Control Procedures
CC1: (to be rendered)
CC2: CC3
job: small check

Bibliography

Teacher

- F. Brucker
- B. François

Sustainable development objectives (SDO)

15-Earth Life
16-Justice and peace

Distribution of hours

Total: 100
Magistrates: 67
Directed work: 3
Practical work: 32

Language(s) used during the course French

DIGITAL

Organisational security of Information Systems

Prerequisites:
Common Trunk Course

Learning Objectives
Have a general idea of the security constraints of an information system, as well as the technical difficulties inherent in its implementation.

Programme Description
- Access
Control Policy and Models - Quality
- Functional Security

Target generic centrale-specific field-related skills and knowledge
Have a general idea of the security constraints of an information system, as well as the technical difficulties inherent in its implementation.

Knowledge Control Procedures
Examination 1: 33%
Exam 2: 33.3333 %
Exam 3: 33,3333333333333%

Teacher
- AMU

Sustainable development objectives (SDO)
2-Fight against hunger
12-Responsible consumption and production

Distribution of hours
Total: 100
Magistrates: 40
Directed work: 30
Practical work: 30

Language(s) used during the course French

DIGITAL

Algorithms

Prerequisites:
Common Trunk Course

Learning Objectives
The purpose of this option is to provide the methodological tools that will allow students to participate in the development of computer codes that are safe and effective. These issues of efficiency and security will be studied according to different programming paradigms (sequential or parallel).

Programme Description
This option will be in four parts:
- Algorithm: algorithm design methods, advanced data structures, graphs, geometric algorithms
- Operational search: Exact and Approached Methods
- Introduction to Real Time: process and communication between processes
- High Performance Computing: efficient use of parallelism

Target generic centrale-specific field-related skills and knowledge
The purpose of this option is to provide the methodological tools that will allow students to participate in the development of computer codes that are safe and effective. These issues of efficiency and security will be studied according to different programming paradigms (sequential or parallel).

Knowledge Control Procedures
CC1 - writes: 42.17%
CC2 - Practical Work: 31.65%
CC3 - Practical Work: 29.78%
CC4 - duty: 16,64%

Bibliography
A. Descartes, *The Method Speech*.

Teacher
- F. Brucker (ECM)
- G. Dias da Fonseca (AMU)
- JR. Herrero (UPC Barcelona)
- E. Daucé (ECM)
- G. Perrot (NVidia)
- P. Préa (ECM)

Sustainable development objectives (SDO)

5-Gender equality
14-Aquatic Life

Distribution of hours

Total: 100
Magistrates: 81
Practical work: 39

Language(s) used during the course French

COMMON TRUNK

Languages - International Cultures 5

Prerequisites: No

Learning Objectives

LCI education is part of the training of · citizens · s and · engineers · international engineers · experts · and · .

The Central Engineer of Marseille will have to be able to interact accurately and effectively with partners from different languages and/or cultures, especially in a professional environment. He/she will be able to mobilise linguistic, conceptual, cultural and communicational knowledge and skills. To do this he/she will acquire knowledge of historical, cultural, social, economic and political practices, events and/or phenomena. He/she will stimulate his/her imagination through cultural discovery and awareness of difference by varying his/her representations. He/she will develop his/her critical mind.

Programme Description

The EU LCI is divided into 2 parts corresponding to 2 language courses (50% of the score each). In order to validate the EU, the student · must obtain an average of 10/20 and a minimum of 7/20 for each language.

According to the CECRL, 5 skills will be evaluated (the number and type of proficiency assessments will be specified by the teacher · according to the level and theme of the group): written understanding and expression, oral comprehension, continuous and interacting oral expression. The knowledge gained will also be assessed and the grades included in the ongoing monitoring assessment. These skills will be evaluated during ongoing or stand-alone activities (personal work to be included in the continuous monitoring evaluation).

Attention: The presence is therefore mandatory: continuous monitoring involves student attendance. Therefore, more than 2 absences will compromise the validation of the semester, any absence will have to be justified with the teachers · and · s and the contents of the sessions will be remedied.

Sessions 2 will address the unvalidated skills in session 1 and will be managed individually by the teachers · and · s.Compulsory external

levels and certifications for obtaining the diploma:

- Obtaining an external certification in English is obligatory (minimum level required B2+ or Toeic 850).
-International students must also validate a minimum level B2 of CECRL in French Foreign Language (Delf B2 or Dalf C1 C2). Attention: the others will have to validate a level of French Mother tongue (Orthodidact level 3).
- In other languages, the target level is B2, or even C1 depending on the student's background. External certification is recommended to certify the highest level of completion of training.

Target generic centrale-specific field-related skills and knowledge

Training in Languages and Cultures is essential to the identity of the · Engineer · Central American who will be able to communicate and interact internationally. The skills of the Central Engineer repository specifically targeted by LCI's teachings will be related to:
- C1: the Central Engineer creates value through scientific and technical innovation.
- C2: ICR has mastered the complexity of the systems and the problems it faces.
- C3: ICR conducts programmes.
- C4: IC manages in an ethical and responsible manner.
- C5: ICR is part of a strategic vision and knows how to implement it.

Knowledge Control Procedures

2 languages (50% each of the average). Minimum of 7/20 for each language.

The 5 skills of CECRL will be evaluated (modalities specified by the teacher · e).

Attention: required attendance: more than 2 absences will compromise the validation of the semester.
Sessions 2 will address unvalidated skills in session 1 and will be managed individually by teachers · s ·.

Teacher

- English: P. Atkinson, J. Airey, V. Durbec (Head of EU), G. Marquis, M. McKimmie
- Spanish: C. Enoch (responsible for LV2), S. Duran, S. Carmoni, E. Munoz, K. Pinchenet
- German: D. Ortelli van Sloun
- FLE: V. Hamel, Dominique Betton
- Chinese: J. Dong
- Japanese: K. Yoshida,
- Italian: S. Canzonieri
- Arabic: B. Zoubir
- Russian: Y. Yurchenko
- Portuguese: S. Almeida

Sustainable development objectives (SDO)

5-Gender equality
7-Use of renewable energy
10-Reducing Inequality
12-Responsible consumption and production
16-Justice and peace

Distribution of hours

Total: 60
Directed work: 60
Applied Jobs: 20

Language(s) used during the course French and English

CliMaTHs

Carbon balance certificate

Prerequisites: No

Learning Objectives
Students will learn to carry out the carbon balance of a
company thanks to the Institut Formation Carbone, delegated by Association Bilan Carbone, the only organisation in France authorised to issue licences for use and exploitation
to carry out a carbon balance.
BC Certification.

Programme Description
Programme defined by ABC

Target generic centrale-specific field-related skills and knowledge
Knowledge Control Procedures IFC Online Review

Bibliography
ABC site.

Teacher
- G. Quiquerez (ECM)

Sustainable development objectives (SDO)
13-Combating climate change

Distribution of hours
Total: 6
Magistrates: 6

Language(s) used during the course French

CliMaTHs

Harmonisation in Analysis and Statistics

Prerequisites
Mathematics and Computer Science Course 1A

Learning Objectives
- Attain the level of mathematics courses (MIE, 2a), S8 DMC and be autonomous in python programming.
- Understanding Fluid Mechanics EDPs

Programme Description
- Analysis of EDP and approximation
- Probability, statistics
- Python programming

Knowledge Control Procedures
Project

Bibliography
MIE, S8 DMC.

Teacher
- Mr. Tournus
- C. Daaloul
- J. Liandrat (ECM)
- T. Goudon (INRIA)

Distribution of hours
Total: 34
Magistrates: 20
Directed work: 7
Practical work: 7

Language(s) used during the course French

CliMaTHs

Introductory Course

Prerequisites: No

Learning Objectives
Understanding Energy/Economy/Climate Issues

Programme Description
Presentation of the ecological, climate, economic, societal, political issues, their understanding and possible ways to control them.

Target generic centrale-specific field-related skills and knowledge

Knowledge Control Procedures
Continuous control quiz

Bibliography
Alain
Grandjean WebsiteYouTube The wakeup machine

Teacher
- A. Grandjean
- R. Meyer

Sustainable development objectives (SDO)
12-Responsible consumption and production
13-Combating climate change

Distribution of hours
Total: 12
Magistrates: 12

Language(s) used during the course French

MECA

New and renewable energy

Prerequisites: No

Learning Objectives

The objective of this module on new and renewable energies is to propose an overview of the main processes envisaged to produce energy in the future, limiting themselves to those processes for which fluid mechanics plays a major role, such as for wind turbines or hydroliners. This part of the course, less detailed than the corresponding parts of the S8 Sustainable Energy of the École centrale de Marseille, is sufficient for students who do not have the objective of specialising in this field and especially for those, the most numerous, who have completed their S8 in international mobility. It is supplemented by two sessions on the system modelling of energy sets (Bond Graph method).
The evaluation consists of a 4-hour TP session, either on a fuel cell bench or on a laboratory wind turbine installed in a wind tunnel, and a continuous monitoring of the implementation of the Bond Graph method. However, this module opens up a wide range of opportunities for students to complete their studies or to take on new jobs, as we see every year.

Programme Description

The lessons learned in this module are divided into four sessions of four hours each, focusing on, respectively, socio-economic aspects and issues related to climate change, wind turbines, marine renewable energies, as well as fuel cells and the hydrogen sector. As well as two other four-hour sessions on system modelling and, in particular, the Bond Graph method, which is very commonly used to analyse and optimise the operation of complex systems, such as those encountered in the field of renewable energy. Specific cases are treated as examples.

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and Technical
Innovation - C2: Control of complexity and systems:
- Know how to analyse an energy problem and know how to propose solutions adapted in terms of renewable energies (C2)
- Know how to interpret results of experience in order to optimise a choice or a functioning (C2)
- C3: Programme management:
- Know how to lead the implementation of a renewable energy programme (choice of the optimal technical/financial solution), as well as the management of its implementation (construction, technical follow-up, management of those involved...)

Knowledge Control Procedures

TP (50%) and CC (50%)

Bibliography

G. Dauphin-Tanguy, *Les Bond Graphs*, Hermès (2000).
D. Le Gouriérès, *Les Éoliennes*, Éditions du Moulin Cadiou (2008).
G. Sarlos, P. A. Haldi, P. Verstraete, *Energy Systems*, Presses polytechnique et universitaire romandes (2003).

Teacher

- F. Anselmet (ECM)
- O. Boiron (ECM)
- O. Kimmoun (ECM)
- Teachers of the AMU, Ministry of the Environment

Sustainable development objectives (SDO)

7-Use of renewable energy
11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 28
Magistrates: 22
Directed work: 2
Practical work: 4

Language(s) used during the course French

PICSEL

Advanced Imaging for Biomedical

Prerequisites:

Geometric optics, signal processing bases,
Maxwell equationsElements of a living cell

Learning Objectives

- Grasp the basics of biomedical and biological imaging from the interaction between waves and matter to the treatment of the images obtained.
- Be aware of the different imaging techniques including both acquisition and restitution of the image at all scales of living organisms, in vivo or in vitro for applications in biology or medicine.
- Have an idea of current and future issues and needs in the field.

Programme Description

The basics of IT (Image Processing):
- digital image, filtering, segmentation, restoration and inverse problems.
Multidimensional image processing:
- machine learning and deep learning for
classificationGeometric optics:
-basic notions of geometric optics, application to
microscopesPhysical principles of the organisation of a living cell:
- Definition of the living cell, interactions, the physical-chemical compartmentalisation of the cell, its spatial-temporal organisation dynamics.
- Understanding parameters describing the complexity of living through instruments (electron microscopy and photonic microscopy)
Imaging biological systems:
- Cell imaging: The optical Microscope, Fluorescence microscopy, Vibrational microscopies, Superresolution techniques, Advanced optical microscopy techniques, applications
- Tissue imaging and biomedical applications: Introduction to biological tissue optics, contrasts (Absorption, fluorescence, Scattering), Model of light propagation, Instrumentation and imaging/diagnostic setups examplesUltrasonic biomedical imaging:
- Basic principle of ultrasound, Quantitative ultrasonic imaging, tissue microstructures, elastography principle, biomarkers, contrast imaging
Biophotonic sensors:
- Principle of surface and volume plasmon resonance - application to microfluidic imaging and detection of pathogensMRI: Magnetic Resonance Imaging
- Ceramics
- The basics of MRI: magnetic properties, polarisation, resonance, relaxation, image reconstruction
- From theory to medical applications and equipment

Target generic centrale-specific field-related skills and knowledge

This discipline is an opening towards the field of medicine and briefly introduces various imaging tools. Two specific skills are targeted:
– C1 (scientific and technical innovation): a good knowledge of the foundations of biomedical

and biological imaging associated with a view of their applications and issues for physicians and/or biologists to reveal the potential of these techniques.
- C2 (Mastery of the complexity of systems): this course allows application of, and extends the physical and image processing notions to the case of living matter, which, by its nature is a complex system.

Knowledge Control Procedures

Image Processing: 45% of the final score (continuous monitoring, average reporting)
Imaging biological systems: 45% of final mark (exam)
Sensors: 10% of final grade (continuous checking, document analysis)

Bibliography

Course materialsI.N. Bankman, *Handbook of Medical Image Processing and Analysis* (2009).

Valery Tuchin, Tissue optics: Light scattering methods and instruments for medical diagnosis, 3rd edition (2015).
Marcel Locquin and Maurice Langeron, Handbook of Microscopy, 1st edition (1983).

Teacher

- Læ titia ABEL-TIBERINI, Salah Bourennane, Frédéric Lemarquis, Muriel Roche ECM teachers - Julien Sein, Émilie Franceschini, Didier Marguet: Vacancy teachers, specialists outside the ECM

Sustainable development objectives (SDO)

3-Access to Health
15-Earth Life

Distribution of hours

Total: 80
Magistrates: 68
Directed work: 4
Practical work: 8

Language(s) used during the course French

DDEFI

DDEFI Project

Prerequisites: No

Learning Objectives
- Carry out a group project in a concrete framework
- Know how to work in team
- Acquire an approach methodology to business problems
- Exploit the tools learned during the track courses in a concrete framework
- Know how to choose among models or solutions
- Know how to use data to take decisions
- Know how to present a model (or a solution), its results and its insights
- Be able to understand the business of a company and the related issues

Programme Description
In groups of 3 to 5, students work on a project proposed by a company. This project gives them the opportunity to extend their knowledge and skills in a particular field by dealing with a practical issue. The subject is proposed by a financial company (bank, insurer), a consulting firm or a start-up.

Each group is guided by an academic and a professional tutor. Meetings are organized regularly for students to present their progress and tutors to clarify the needs of the project.

The project concludes with a presentation, where students present the business and issues faced by the company, their proposed solution and lessons learned from the running of the project.

Knowledge Control Procedures
Project deliverables and presentation

Teacher
- Renaud Bourlès (Centrale Marseille)
- Nicolas Clootens (Centrale Marseille)
- Dominique Henriet (Centrale Marseille)
- Florian Magnani (Centrale Marseille)
- Françoise Perrin (Centrale Marseille)
- Christophe Pouet (Centrale Marseille)

Sustainable development objectives (SDO)
7-Use of renewable energy
9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 100
Projects: 100

Language(s) used during the course French

DDEFI

Speciality: Analysis and Data

Prerequisites:

The Data and Decision Unit of DDEFi and its own prerequisites

Learning Objectives

– Know how to use data in a strategic approach
– Know how to present a model, its results and its insights
– Know how to assess suitability of data to treat a specific issue
– Know how to model intertemporal strategic decisions
– Know how to combine model and data to make pricing decisions
– Understand the importance of methodological choices when building indexes and indicators
– Know how macroeconomic indices are built and used

Programme Description

This unit is composed of three courses (lasting 24 hours each): Quantitative marketing, Data and macroeconomics, and Yield management, with the following outline
Quantitative marketing
1. Data processing
a. Data: a story of representation
b. Data in business
c. From segmentation to dynamic targeting
2. Marketing from a Data Scientist point of view
a. Context: the world of data
b. Scoring
c. Statistics
d. Correlations
e. Automatic learning
f. Supervised classification
g. Perspectives

Data and macroeconomics
This course aims to provide a broad view of macroeconomic data. It is structured around the following three questions:
1. Can everything be measured?
2. Can everything be summed?
3. Can everything be compared?
These questions will be used to tackle multiple sources of macroeconomic data, applicable methodology, limitations, and to discuss common applications. At the end of the course, students should have acquired enough knowledge to use relevant macroeconomic data to answer a practical question.
Yield management
1. Dynamic pricing
a. Modelling a firm's intertemporal price-setting decisions
b. The price-quality relationship

c. Modelling project: managerial decision in an intertemporal framework.
2. Application to yield management in air transport
a. Single-leg resource management
b. Network resource management
c. Demand forecasting

Knowledge Control Procedures

Group project and presentation (Quantitative marketing): 35%
Project (Data and macroeconomics): 35%
Project (Yield management): 30%

Bibliography

Marketing
Quantitative - Abiteboul, *Data Sciences: from first order logic to the Web*.
Data and macroeconomics
- insee.fr
- https://datagora.fr/
Yield management
- Talluri, Van Ryzin, The Theory and Practice of Revenue Management

Teacher

- Augustin Amann (S4M, Quantitative marketing)
- Vincent Archer (S4M, Quantitative marketing)
-Aurélien Poissonier (DGAFP, Data and macroeconomics)
- Régis Chenavaz (Kedge BS, Yield management)
-Antoine Winckels (Air France, Yield management)

Sustainable development objectives (SDO)

10-Reducing Inequality

Distribution of hours

Total: 80
Magistrates: 72
Directed work
Practical work
Applied
Projects: 8
Other

Language(s) used during the course French

DDEFI

Specialisation: Actuarial sciences

Prerequisites:

The Data and Decision Unit of DDEFi and its own prerequisites

Learning Objectives

– Understand how individual behaviours aggregate in the insurance market and how prices are determined
– Know the principles behind the pricing of insurance products and be able to apply them to simple products
– Understand the need for provisioning and know the basic model by which to compute provisions
– Know how to choose a pricing model based on the risks and issues faced by an insurer
– Know the current regulations and how they affect insurance pricing and provisioning
– Know how to value an insurance portfolio

Programme Description

This unit is composed of three courses (lasting 24 hours each): Economics of insurance, Actuarial science 1, Actuarial science 2, with the following outline:
Economics of insurance
1. Introduction: Attitude to risk and preferences
2. The single-risk model
3. Product differentiation
4. Unobservable criteria
5. Moral hazard
6. Extensions and exercises
7. Topic: Duration models and actuarial tables
Actuarial science 1
1. Introduction to actuarial science
a. Life insurance model: fair premiums and prudent pricing
b. Non-life specificities: provisioning for and variability of non-life risks
2. Life insurance, savings products, and accounting
a. Introduction to Mathematical Reserves
b. Savings contracts and performance distribution mechanisms
c. Performance indicators for an insurance company
3. Non-Life Insurance
a. Non-Life Insurance Mechanisms
b. Loss experience and reserving
c. Introduction to Non-Life Reinsurance
Actuarial science 2
1. Valuing an insurance portfolio
2. Asset-liability management in insurance
3. Accounting and financial communication for insurance companies
4. The current regulations: IFRS17

5. CAT risk and CAT reinsurance
6. Focus on long-term care

Knowledge Control Procedures
Written exam: 30 %
Project (Science Actuarial 1): 40 %
Written exam (Actuarial science 2): 30%

Bibliography
Economics of
insurancePicard, Economic Analysis of Insurance Fraud, Handbook of Insurance.
Schlessinger, The Theory of Insurance Demand, Handbook of Insurance.
Actuarial science 1 & 2
Charpentier, Computational Actuarial Science with R.
Tosetti, Weiss and Poncelin, *The tools of actuarial life.*

Teacher
- Renaud Bourlès (Centrale Marseille)
- Corinne Cherki (AXA)
- Alban Davand (AXA)
- Xavier Guerrault (AXA)
- Carelle Merlo (AXA)
- Emmanuelle Mimart (AXA)
- Renaud Mouyrin (AXA)
- Sofiane Ournidi (AXA)
- YXA annick Ropert (AXA)
- Matthias Servel (AXA)
- Émilie Soix (AXA)

Sustainable development objectives (SDO)
3-Access to Health

Distribution of hours
Total: 80
Magistrates: 72
Projects: 8

Language(s) used during the course English

DDEFI

Data and Decision

Prerequisites:

The Models and decision unit of DDEFi and its own prerequisites

Learning Objectives

– Know how to model and program an estimation problem
– Know how to model and program a classification problem
– Be able to build performance indicators for a model applied to a dataset
– Know how to choose between models or solutions
– Know how to acquire and aggregate data
– Know how to use data to make decisions
– Know which data to use to make decisions
– Understand the importance of data governance and data quality
– Understand and measure the value of data

Programme Description

This unit is composed of three courses (lasting 24 hours each): Statistical learning, Python for data science, and Advising using data, with the following outline
Statistical learning
1. Introduction
a. Classical problems: regression, classification
b. Supervised, unsupervised and semi-supervised learning
c. Curse of dimensionality
2. Regression
a. OLS method
b. Shrinkage-type methods (LASSO, Ridge, ElasticNet)
c. K-Nearest Neighbours
d. Regression tree
3. Classification
a. Linear Discriminant Analysis
b. Classification tree
c. K-Nearest Neighbours
d. SVM
e. Artificial Neural Networks
Python for data science
1. Dataframe: data exploration and data description
2. Spotting patterns using factors
a. Principal Component Analysis
b. Correspondence analysis
3. Prediction using trend analysis
a. Linear regression
b. Logistic regression
4. Data classification
a. Classification using partition

b. Hierarchical methods
Data-driven decision-making
1. What is data?
2. How do we make decisions?
3. Data governance and data quality
4. How can we develop data-based decision-making?
5. Data platform and data architecture

Knowledge Control Procedures

Project (Statistical learning): 30 %
Project (Python for data science): 35 %
Group project and presentation: 35%

Bibliography

Hastie, Tibshirani and Friedman (2013), *The elements of statistical learning: data mining, inference, and prediction*.
James, Witten, Hastie, and al. (2013), *An introduction to statistical learning: with applications in R*.
Jannach, Zanker, Felfernig, and Friedrich (2010), *Recommender Systems: An Introduction.*

Teacher

- Christophe Pouet (Centrale Marseille, Statistical learning)
- François Brucker (Centrale Marseille, Python for data science)
- Emmanuel Daucé (Centrale Marseille, Python for data science)
- Michaël Chalamel (L'Oréal, Data-driven decision making)
- Franck Chevalier (EY, Data-driven decision making)

Distribution of hours

Total: 80
Magistrates: 72
Projects: 8

Language(s) used during the course French

DDEFI

Specialisation: Company finance

Prerequisites:

The "Finance" unit of DDEFi and its own prerequisites

Learning Objectives

– Know how to build a financial model and challenge its assumptions
– Know how to produce financial information
– Understand how bankers can manage risks using structured finance
– Know the advantages and drawbacks of structured operations
– Understand how these operations can be used to finance large industrial projects
– Know the advantages and drawbacks of PPPs
– Understanding the specificities of start-up financing and mentoring

Programme Description

This unit is composed of three courses (lasting 24 hours each): Structured finance, Project finance, and Corporate finance workshop, with the following outline

Structured finance

1. Main market stakeholders and rationale for using structured finance
2. Promoters Credits
a. Understanding the Promoter's logic
b. Understanding Credit Risk
c. Assessing the risks for the banker
3. Investor Credit
a. Conceptualization
b. Leverage and Loan to Value (LTV)
c. Debt Service Cover Ratio (DSCR) and Interest Cover Ratio (ICR)
d. Debt Slicing
4. Due diligence and points of vigilance for bankers
a. Leases and Rental Conditions
b. Valuation Report
5. Other operations
6. Perspectives on Market Finance (Securitization)

Project finance

1. The main steps in project finance
a. Tender
b. Structuring
c. Optimization
2. Financial modelling
a. The issue of circularity
b. Internal rate of return and gearing ratio
c. Case study
3. The case of renewable energy projects
a. Prices of and costs linked to renewables
b. Bank vs funds
c. How is the price of a project set?

Corporate finance workshop
1. Financial modelling using Excel
2. Specificities of Transaction Advisory Services
3. Advising start-ups (on their business model and to ensure viability)
4. Projects with real start-ups

Knowledge Control Procedures

Group project and presentation (Structured finance): 30 %
Project finance: 35 %
Group project and presentation (Workshop): 35%

Bibliography

Vernimmen, P. (2021), *Corporate Finance*, Dalloz

Teacher

- Amaury Schoenauer (CEPAC Savings Bank)
- Mehdi El Alaoui (International Finance Corporation)
- Benoît Forgues (Rgreen)
- Olivier Vandooren (Sigée Finance)
- Julien Belon (Arx Corporate Finance)
- Hugues Chabalier (2CFinance)
- Mathieu Rebbi (EY)

Sustainable development objectives (SDO)

7-Use of renewable energy
9-Building Resilient Infrastructure
17-Partnerships for the achievement of objectives

Distribution of hours

Total: 80
Magistrates: 64
Projects: 16

Language(s) used during the course English

DDEFI

Specialisation: Financial mathematics

Prerequisites:

The "Finance" unit of DDEFi and its own prerequisites

Learning Objectives

– Understand stochastic calculus and know how to apply its main results
– Know how to apply stochastic methods to price financial products
– Understand the mathematical contexts under which classical financial mathematical models hold
– Know and understand the relevance and limitations of financial mathematical models
– Understand the impact of volatility on profits and losses for hedged positions
– Know how to build numerical methods to price financial products

Programme Description

This unit is composed of three courses (lasting 24 hours each): Stochastic calculus, Interest rate models, and Volatility modelling, with the following outline

Stochastic calculus

1. Gaussian variable and stochastic processes
2. Brownian motion
3. Stochastic integration and semi-martingales
4. Stochastic differential equations
5. Parabolic partial differential equations and semigroups
6. Change measurement and Girsanov theorem
7. Introduction to financial mathematics

Interest rate models

1. A Mathematical Toolkit
2. Interest rates, swaps and options
3. One-factor Short-Rate Models
4. Two-factor Short-Rate Models
5. Health-Jarrow-Morton (HJM) Model
6. Change of numeraire
7. Derivative Pricing under the LIBOR Market Model

Volatility models

0. Elementary notions in financial mathematics
1. PDE: Black Scholes and risk-neutral measurement
2. Dupire's local volatility: advantages and drawbacks
3. Stochastic volatility (Heston and SABR)
4. Tutorial: discretization of Heston's model

Knowledge Control Procedures

Written exam: 30 %
Project (Interest rate models): 35 %
Project (Volatility models): 35%

Bibliography

- Stochastic
calculusEvans (2010), *An Introduction to Stochastic Differential Equation*.
- Volatility
modelsEl Karoui (2004), *Risk hedging in financial markets*.
- Interest rate
modelsBrigo and Mercurio (2007), *rate models -theory and practice: with smile, inflation and credit*.
Privault, N. (2012), *An elementary introduction to stochastic interest rate modelling*.

Teacher

- Sébastien Darses (AMU, Stochastic calculus)
- Abderrahim Ben Jazia (RSM Paris, Interest rate models)
-Ismail Akil (Morgan Stanley, Volatility models)

Distribution of hours

Total: 80
Magistrates: 72
Projects: 8

Language(s) used during the course English

DDEFI

Finance

Prerequisites:
The "Models and decision" unit of DDEFi and its own prerequisites

Learning Objectives
– Understand the similarities in concepts used in market finance and in corporate finance
– Understand how financial products can be used to manage risk
– Know how to organize and manage an investment process
– Know how to assess and value a company
– Understand the definition, measurement and pricing of credit risk
– Know the various banking risks and how banks are regulated
– Know the various roles and occupations in finance

Programme Description
This unit is composed of three courses (lasting 24 hours each): Portfolio management, Applied finance, and Credit risk, with the following outline

Portfolio management
1. Introduction to portfolio management
2. Equity Investing and investment process
3. Fixed-Income Investing – basics
4. Fixed-Income Investing – advanced
5. Alternative asset classes and Performance Measurement
6. Asset management trends
7. Project: Portfolio construction

Applied finance
1. Applied corporate finance – From start-up to IPO... and LBO
a. Introduction/Presentation
b. Areas of application
c. Basic Accounting Methods
d. Valuation methods
e. We know how to value a company. Now what? Different types of operation
f. Introduction to Fintech and the ecosystem of start-ups
2. Applied market finance – Options: Pricing, Hedging & Risk Management
a. Market finance: stakeholders and products
b. The future and beyond: pricing & hedging
c. Options: replication and pricing
d. Sensitivity of options: the Greeks
e. Volatility and stress tests

Credit risk
1. Introduction: bonds and OTC transactions
2. Modelling defaults: structural models and ratings

3. Structured financing: plain-vanilla, asset financing, securitization, etc.
4. Banking regulations related to credit risk

Knowledge Control Procedures

Written exam (Credit risk): 30 %
Group project and presentation (Portfolio management): 35 %
Projects (Applied finance): 35%

Bibliography

Portfolio management
- Portat and Poncet (2014), *Market Finance*.
- Fabozzi (2012), *The Handbook of Fixed Income Securities.*
Applied finance
- Vernimmen (2021), *Corporate Finance.*
- Hull (2018) *Options, Futures, and Other Derivatives.*
Credit risk
- Roncalli (2016), *Risk Management & Financial Regulation.*

Teacher

- Grégoire Hug (WeeFin, Portfolio management)
- Julien Belon (ARX Corporate finance, Applied finance)
- Vincent Bonnamy (La Banque Postal Asset Management, Applied finance)
- Antoine Godin (Quant Digital AM, Credit risk)

Sustainable development objectives (SDO)

12-Responsible consumption and production

Distribution of hours

Total: 80
Magistrates: 72
Projects: 8

Language(s) used during the course English

DDEFI

Models and Decisions

Prerequisites:

– Grounding in Probability and Statistics (common courses of the first two years of the engineering program)
– Basic Accounting (common course of the first year of the engineering program)
– Basic Finance (equivalent of the elective course of the second year of the engineering program)

Learning Objectives

– Understand how a decision-maker can assess risks
– Know how to model decision-making with a certain level of uncertainty
– Learn various ways to compare risky situations, their advantages and drawbacks
– Learn how to model, estimate and predict time series
– Know how to identify and validate a time series model
– Understand how capital structure affects a firm's value
– Know how to conduct and present a company's financial analysis

Programme Description

This unit is composed of three courses (lasting 24 hours each): Risks and decisions, Statistics and decisions, and Corporate finance, with the following outline
Risks and decisions
1. Introduction: diversification and mutualization
2. Measuring risk
3. Expected utility
4. Supply and demand: pricing risk
5. The value of information
6. Market & Counterparty Risk Management

Statistics and decisions
1. Stochastic processes in discrete and continuous time
2. ARIMA process: definition, existence, characteristics (autocovariance, partial autocovariance)
3. Estimation of ARIMA processes: parameter identification, estimation and validation
4. Extensions: SARIMA, ARCH and GARCH processes

Corporate finance
1. The Corporation
2. Introduction to Financial Statements Analysis
3. Financial Decision-Making and the Law of One Price
4. The Time Value of Money
5. Interest Rates
6. Investment Decision Rules
7. Capital Markets and Pricing of Risk
8. Optimal Portfolio Choice and the Capital Asset Pricing Model

9. Capital Structure in a Perfect Market
10. Financial Distress, Managerial Incentives, and Information
11. Raising Equity Capital

Knowledge Control Procedures

Written examination (Risk and decision): 35%
Test and project (Statistics and decisions): 35 %
Group project (Corporate Finance): 30%

Bibliography

Riskhttp://dhenriet.perso.centrale-marseille.fr/risk/
Gollier, Schlesinger, and Eeckhoudt (2005), *Economic and Financial Decisions Under Risk*.

StatisticsBrockwell and Davis (1991), *Time Series: Theory and Methods*.
Box and Jenkins (1970), *Time Series Analysis; Forecasting and Control*.
- Corporate
financeBerk and DeMarzo (2019), *Corporate finance*.

Teacher

- Dominique Henriet (Centrale Marseille, Risk and decision)
- Clément Depoutre (BNP Paribas, Risk and decision)
- Gaël Lefoeuf (AMU, Corporate Finance)
- Christophe Pouet (Centrale Marseille, Statistics and decisions)

Sustainable development objectives (SDO)

10-Reducing Inequality

Distribution of hours

Total: 80
Magistrates: 58
Directed work: 12
Practical work: 6
Projects: 4

Language(s) used during the course English

DDEFI

Data Project

Prerequisites:
Basic knowledge in data science and Python

Learning Objectives
– Understand the workflow of a data science project in a business context (data acquisition, feature selection and feature engineering)
– Be able to account for business (needs identified, project lifecycle, communication) and technical (data, machine-learning, scaling) constraints
– Know the basic data science models (in particular regression and decision tree) and how they are used
– Discover Natural Language Processing

Programme Description
The course is composed of a theoretical and a practical part, simulating a business project.
The theoretical part is based on the following outline:
1. Data science in business
1.1. Main issues
1.2. Sample data projects
2. Starting a data science project
2.1. Constraints of data science projects
2.2. Finding data
2.3. Acquiring information
2.4. Playing with data
3. Lifecycle of a project
3.1. Bias-Variance trade-off
3.2. Feature Selection
3.3. Feature Engineering
3.4. Defining a metric
4. Basic models
4.1. Regression (linear, polynomial, penalized and logistic)
4.2. Decision trees (random forest and gradient boosting)
5. Focus on Natural Language Processing (NLP)
5.1. Word Embedding
5.2. Example: Analysis of sentiments

Knowledge Control Procedures
Project

Bibliography
Zeng, A and Casari, A, *Feature Engineering for Machine Learning*, O'Reilly Media.
Müller, A. and Guido, S, *Introduction to Machine Learning with Python*, O'Reilly Media.

Teacher
- Alexandre Chirié (Mantiks)
- Maximilien Defourné (Mantiks)

Sustainable development objectives (SDO)
12-Responsible consumption and production

Distribution of hours
Total: 60
Magistrates: 24
Projects: 36

Language(s) used during the course French

MECA

Advanced Fluid Mechanics

Prerequisites: No

Learning Objectives

This EU comprises two modules, each specific to a field of very frequent applications of fluid mechanics, namely aerodynamics and multiphase flows. The skills and knowledge referred to correspond to the minimum level required, either to interact with specialists in these fields or to deal with common classical problems on their own, or to deepen this knowledge by reading specialised books or participating in specialised complementary training courses.

Programme Description

- The 1st module deals with aerodynamics. It includes, on the one hand, the presentation of the theory of the "thin wing", which allows, in particular, thanks to simple tools derived from the theory of potential flows, to evaluate the lift of aircraft wings. On the other hand, the presentation by two representatives of the transport sector (cars and helicopters) of the most recent methods used in the industry makes it possible to clearly identify the hard points that hinder, in particular, their performance. The enormous complexity gap between these two types of approaches justifies that only simplified tools can be exposed in the course. These tools are still used in aeronautics for feasibility and pre-sizing studies.
- The 2nd module concerns multiphase flows. It allows the students to present the theoretical developments specific to these flows, starting first with the most general equations, and then taking specific interest in two specific situations, the liquid/vapour equilibrium flows that occur, in particular, in the nuclear industry, as well as the problems related to aerosols that can be encountered in both industry and the environment (pollution and associated health risks).

Target generic centrale-specific field-related skills and knowledge

- Ability to model and analyse an aerodynamic problem or multiphase flows, choosing the most relevant modelling level (C2)
- Ability to master the numerical modelling/simulation methods associated with these types of situations (C2)
- Ability to interpret experiment results (C2)

Knowledge Control Procedures

For the 1st module, the evaluation is done in the form of a computer mini-project that implements the simple tools presented in this module: 50%.
For the 2nd module, the evaluation is done in the form of a three-hour written evaluation: 50%.

Bibliography

R. Borghi, F. Anselmet, *Modelling of turbulent multi-phase flows out of equilibrium*, Hermes-Lavoisier (2014).
A. Mailliat, *Aerosol media and their representations*, EDP Sciences (2010).
I. Paraschivoiu, *AAAi* Montreal Polytechnic Press (1999).

Teacher

- F. Anselmet (ECM)
- M. Abid (AMU)
- External Industry Executives (CEA/IRSN)

Sustainable development objectives (SDO)

11-Sustainable cities and communities
13-Combating climate change

Distribution of hours

Total: 48
Magistrates: 36
Directed work: 12

Language(s) used during the course French

MECA

Turbulence

Prerequisites: No

Learning Objectives

This EU on turbulence is made up of 2 add-ons. In the first module, the mechanisms for developing hydrodynamic instabilities and the onset of turbulence are presented. Both from the point of view of the phenomenological description and from the point of view of the equation of the associated phenomena in a linear approach. The second module, which focuses on turbulent heat and mass transfers, deepens the knowledge compared to the previous one, with much greater emphasis on practical applications, but also on theoretical analyses that complement and deepen the concepts presented in the first module (notions of invariants of the Reynolds tensor and the "feasibility" of the models, in particular, but also the contribution of Machine Learning methods to the study and modelling of turbulent flows).

Programme Description

- The 1st module first presents the classical elements of the linear theory of instabilities development (notions of threshold, of clean modes...) and then applies them to different situations (instabilities of Kelvin-Helmoltz, of Rayleigh-Bénard, waves of capillarity-gravity). Then we discuss the appearance of turbulence and the necessary use of Reynolds decomposition. The rest of this module presents the most common models of turbulence in the 1st order, with the specificities of each one.
- The 2th module deepens these analyses by focusing on the models of turbulence in the second order and the complexities (pressure-speed coupling in particular) that these models allow to take into account and on the other hand on flows with heat transfer and/or mass that were not covered in the 1st module. This is illustrated by the analysis of many concrete cases of flows encountered in both industry and environmental applications.

Target generic centrale-specific field-related skills and knowledge

- Ability to model and analyse turbulent flows, choosing the most relevant model (C2)
- Ability to master the methods of modelling/numerical simulation of turbulent flows (C2)
- Ability to calculate the main characteristics (turbulent intensities, characteristic scales) of turbulent flows (C2)
- Ability to interpret experiment results (C2)

Knowledge Control Procedures

DS (3 h) for the 1st part: 50% CCPart 2: 50%

Bibliography

M. Abid, F. Anselmet, C. Kharif, *Hydrodynamic instabilities and turbulence*, Cépaduès Éditions (2017).
F. Charru, *Hydrodynamic instabilities*, EDP Sciences (2007).
P. Chassaing, *Turbulence in fluid mechanics*, Éditions (2000).

Teacher

- F. Anselmet (ECM)
- M. Abid (AMU)

Sustainable development objectives (SDO)

7-Use of renewable energy
13-Combating climate change

Distribution of hours

Total: 48
Magistrates: 36
Directed work: 12

Language(s) used during the course French

MECA

Acoustic Aero

Prerequisites: No

Learning Objectives

This course presents concepts and phenomena specific to sound generation and its propagation in fluid environments at rest or in motion, as well as the basics of aeroacoustics. The aim of the course is to enable a student, when he or she is an engineer, to master the basic mathematical and physical concepts necessary to solve problems of acoustics, aeroacoustics and vibration, in particular by using commercial digital tools: know how to evaluate reasonable orders of magnitude, know how to master the various levels of approximation involved in these numerical modelling tools, know how to interpret and critically analyse the results obtained, etc.
There are no specific prerequisites. The 1st year continuous mechanical/mechanical courses are sufficient.

Programme Description

The course is organised in two parts.
- In part 1st, we first recall the basics of acoustics (notions on waves and propagation, different types of sources ...), then examine different applications (propagation in a stratified atmosphere or in a confined environment ...).
- In part 2nd, we focus specifically on aeroacoustics its experimental characterisation and modelling for the implementation of numerical simulations. For this, we present the classic models, and of increasing complexity, that are for example the approaches of Lighthill, Ribner or Corcos. Finally, some recent examples of numerical simulations illustrate the limitations of these models.

Target generic centrale-specific field-related skills and knowledge

- Knowledge of modelling and analysing acoustic or aeroacoustic phenomena (C2)
- Knowledge of numerical modelling/simulation methods of acoustic or aeroacoustic phenomena (C2)
- Knowledge of calculating the main characteristics (levels, frequency peaks) of acoustic or aeroacoustic phenomena (C2)
- Knowledge of interpreting experiment results (C2)

Knowledge Control Procedures

Duty monitored: 3

Bibliography

F. Anselmet, P.O. Mattei, *Acoustics, Aeroacoustics and Vibrations*, ISTE Éditions (2015).
S. Lévy, *Industrial and Aeroacoustic Acoustics*, Hermès (2002).

Teacher

- F. Anselmet (ECM)
- Y. Knapp (University of Avignon and the Vaucluse countries)

Sustainable development objectives (SDO)

11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours

Total: 24
Magistrates: 18
Directed work: 6

Language(s) used during the course French

DIGITAL

Internet of Things

Prerequisites:

This time-programmed teaching aggregates topics studied in Common Trunk and other electives.

Learning Objectives

The Internet of Things (IoT) refers to the rapidly expanding network of devices that connect to the Internet for the collection, processing and exchange of data to optimise the use of our physical environment.
This "web" transforms the conventional approach of automation that links the consideration of the parameters of our environment to the actions that can be exercised on it with objectives on resilience, performance and reliability The objective

of this option is to introduce students to the Digital-e “ecosystem” path enabling the development of IoT solutions by highlighting what can be a hindrance to its deployment: The approach
chosen is a project-based approach that best balances the areas of expertise to be acquired in developing and implementing IoT solutions.

Programme Description

This option is composed of several modules:

- Introduction to IoT: definition, history, issues, ecosystem, architecture, radio protocols and application interfaces, use cases, implementation.

-Real-time introduction: process & communication between processes, use of semaphores.

- Embedded code: microarchitecture, impact of microarchitecture on software performance and software security, embedded software architecture.

-Auxiliary attacks/channels & error injection: Auxiliary Channel Attacks, Fault Injection.

- Networks and network protocols for IoT: data transmissions, OSI and TCP/IP models, IPv4 addressing, ARP, IP, ICMP, TCP, UDP, DHCP, HTTP, SSL/TLS, POP/IMAP/SMTP, SNMP, C-socket programming, attacks and defences of web applications, architectures and network components.

- Security: methodologies used to model security aspects of a system, GDPR, use of cryptography to design secure protocols, security of popular IoT protocols (TLS, BLE, LoRa), security/performance/functionality trade-offs: on two STM32/STSAFE product families.

Target generic centrale-specific field-related skills and knowledge

This training complements the implementation of the "system" approach that is essential in:
- The development of technical and scientific innovations
- The resolution of complex and transdisciplinary problemsIt allows to evaluate the ability of the student to propose connected solutions for a system, and to exploit them to supervise or control that system.

Knowledge Control Procedures

Continuous monitoring: a number of tests (small questions, TP, mini-projects...) will be required.
The score will be a weighted average.

Bibliography

The Technical Foundations of IoT, Raspberry Pi IoT Projects, IoT, Technical Challenges and Solutions.

Teacher

- Mr. Agoyan (ST)
- F. Brucker (ECM)
- S. Courcambeck (ST)
- A. Kilidjian (ECM)
- P. Préa (ECM)
- O. Marine (Cyberwings)

Sustainable development objectives (SDO)

3-Access to Health
6-Access to safe water and sanitation
7-Use of renewable energy
9-Building Resilient Infrastructure
11-Sustainable cities and communities

Distribution of hours

Total: 100
Magistrates: 52
Practical work: 48

Language(s) used during the course French

GREEN

Process Control

Prerequisites:
Continuous-time linear systems, Unit Operations, Process Design

Learning Objectives
Without describing detail or reiterating the justification of all the physical principles encountered in the various disciplines involved, the approach adopted is to establish analogies and proposes approaches to obtain a mathematical model that can be used to control, the behaviour of the process.
- A part is dedicated to the control itself, offers solutions adapted to different types of process.

This module will allow students to extend their skills in the field of control. Approaches adapted to the specificity of the very nature of the processes that constitute the production units will be addressed.

Programme Description
Theoretical aspects:
- Dynamics of systems - Modelling
- Concept of dynamic system
- Mathematical description
- Operative procedure
- Differential Equation - Transfer Function. Example
- Non linearity
- State equation

- Process control:
- Finality
- PID controllers - setting methods
- Limitations of PID
- Improved PID - Cascade Control - Split range - Over ride control - Feed forward control - Internal Model Control
- Systems with delay - PIR
- Discrete-time Control Systems. Stability - Steady state errors. Control design
- Predictive

approachPractical teachings:
- Use cases

Target generic centrale-specific field-related skills and knowledge
Contribution to the:
- Mastering the complexity of systems
- Development of technical and scientific innovations in chemical process
- Solving complex problems

- Solving trans-disciplinary problems requiring the introduction of process control

Knowledge Control Procedures
Continuous assessment - practical work

Bibliography
Books available in the library (JP. Couriou, R. Lonchamp).

Teacher
- Alain Kilidjian

Sustainable development objectives (SDO)
2-Fight against hunger
3-Access to Health
6-Access to safe water and sanitation
12-Responsible consumption and production

Distribution of hours
Total: 25
Magistrates: 13
Practical work: 12

Language(s) used during the course: French

DIGITAL

Statistical Engineering and Applications and Deepening (ISAA)

Prerequisites:

Common course of mathematics and signal processing of the first year of the École Centrale de Marseille.

Learning Objectives

The engineer is provided with the methodological basis for statistical engineering to formulate and resolve engineering problems using statistical techniques. The trained engineers will be able to master the statistical tools for describing and analysing data for a wide variety of applications. Examples include autonomous systems, physical systems or industrial processes. These very general concepts can also be very useful for quality, advice or logistics.

Programme Description

- Further study on the notions of random for statistics and information processing
- Standard and Bayesian statistical methods for tasks such as: Parameter estimation, event detection or data classification
- Data classification methods and learning techniques
- Data modelling (time series, multivariate data...)
- Data representation and correlation finding
- Presentation of the essential notions of information theory and applications
- Deepening performance boundaries (for estimation, detection) and their practical use
- Introduction to the concepts of complexity in applied statistics
- Illustrations and applications on many different examples

Target generic centrale-specific field-related skills and knowledge

- Define and characterise different data processing systems for many fields of activity
- Master statistical tools for analysis of data from industrial, physical or management systems
- Understand the essential factors in complex systems.

Knowledge Control Procedures

DC:
CC1: 2 writings that contribute 48% of the
final gradeCC2: Practical work reports that contribute to 16% of the
final scoreCC3: Mini-Project 1 report that contributes 16% of the
final gradeCC4: Report on the mini-project 2 which contributes 20% of the final note

Bibliography

Ph Réfréger, *Noise theory and application to physics*, Springer, 2003.
P.H. Garthwaite, I.T. Jolliffe and B. Jones, *Statistical Inference*, Prentice Hall, 1995.
T.M. Cover and J.A. Thomas, *Elements of information theory*, Wiley, 2006.
A. Ruegg, *Stochastic Processes - With applications to waiting and reliability phenomena*, Presses polytechnique et universitaire romandes, 1989.

Teacher

- G. Berardi
- F. Galland
- Ph. Refréger
- A. Roueff

Distribution of hours

Total: 100
Magistrates: 44
Directed work: 14
Practical work: 42

Language(s) used during the course: French

PICSEL

Statistical Engineering and Applications (ISA)

Prerequisites:

Common course of mathematics and signal processing of the first year of the École Centrale de Marseille.

Learning Objectives

The engineer is provided with the methodological basis for statistical engineering to formulate and resolve engineering problems using statistical techniques. The trained engineers will be able to master the statistical tools for describing and analysing data for a wide variety of applications. Examples include autonomous systems, physical systems or industrial processes. These very general concepts can also be very useful for quality, advice or logistics.

Programme Description

- Further study on the notions of random for statistics and information processing
- Standard and Bayesian statistical methods for tasks such as: Parameter estimation, event detection or data classification
- Data classification methods and learning techniques
- Data modelling (time series, multivariate data...)
- Data representation and correlation finding
- Presentation of the essential notions of information theory and applications
- Deepening performance boundaries (for estimation, detection) and their practical use
- Introduction to the concepts of complexity in applied statistics
- Illustrations and applications on many different examples

Target generic centrale-specific field-related skills and knowledge

- Define and characterise different data processing systems for many fields of activity
- Master statistical tools for analysis of data from industrial, physical or management systems - Understand the essential factors in complex systems.

Knowledge Control Procedures

DC:
CC1: 2 writings that contribute 60% of the
final gradeCC2: Practical work reports that contribute 20% of the
final gradeCC3: Report on the mini-project that contributes 20% of the final grade

Bibliography

Ph. Réfréger, *Noise theory and application to physics, Springer*, 2003.
P.H. Garthwaite, I.T. Jolliffe and B. Jones, *Statistical Inference*, Prentice Hall, 1995.
T.M. Cover and J.A. Thomas, *Elements of information theory* , Wiley, 2006.
A. Ruegg, *Stochastic Processes - With Applications to the Phenomena of Waiting and Reliability*, Polytechnic and University Press, 1989.

Teacher

- G. Berardi
- F. Galland
- Ph. Refréger
- A. Roueff

Distribution of hours

Total: 80
Magistrates: 38
Directed work: 14
Practical work: 28

Language(s) used during the course French

MECA

Mechanical software tools

Prerequisites:
Mechanics of the Continuous Environment, Weak Formulations or Virtual Power Theorem

Learning Objectives
- Gain a broad view of software tools using the finite element method in solid mechanics
- Know and know how to use the finite element method in a software framework
- Know the theoretical foundations of the method
- Know how to define a problem in a software framework
- Know how to construct the steps of solving a problem in a software framework
- Master the methods of solving a non-linear problem in this framework
- Analysing and criticising a calculation result

Programme Description
Part 1
- Finite element method: the basics (38 h)
- Theoretical reminders on the MEF
- Presentation and taking over the Abaqus software
- Treatment of various problems related to the courses in the form of TP and a mini-project (sessions with teacher and sessions in autonomy)

Part 2 - Method of finite elements: (10 h)
3 sessions are dedicated with each one a focus on a particular issue, treated more theoretically within another EU:
- SMIN-1: Beams, plates and hulls (4h)
- SMIN-2: Dynamic (mode and FRF calculations, 2 h)
- COMA-2: Large deformations (4h)

Target generic centrale-specific field-related skills and knowledge
- Knowing how to formulate complex problems in a software framework
- Knowing how to analyse and criticise the results of a calculation
- Knowing how to formulate specific development requests for a software
- Knowing how to choose the software best suited to the problems

Knowledge Control Procedures
- CC1: QCM on Part 1 (7.5%)
- CC2: Mini-Project CR for Part 1 (55%)
- CC3: Mini-Project CR for Part 2 (37.5%)

Bibliography

Course Notes (Introduction and theoretical reminders EF) Course
Materials (Part 1).
Course Materials (Part 2).
M. Bonnet and A. Frangi, *Analysis of Deformable Solids by Finite Element Method*, Les éditions de l'École Polytechnique, 2006.
T.J. Hughes, *The finite element method: linear static and dynamic finite element analysis*, Dover, 2012.

Teacher

- Iulian Rosu (CNRS Research Engineer, Laboratory of Mechanics and Acoustics)
- Stéphane Bourgeois
- Stéphane Lejeune (CNRS Research Engineer, Laboratory of Mechanics and Acoustics)
- Emmanuelle Sarrouy

Distribution of hours

Total: 48
Magistrates: 8
Directed work: 8
Practical work: 32

Language(s) used during the course English

MECA

Civil engineering

Prerequisites:
Mechanics of continuous environments

Learning Objectives
- To give a general overview of the different types of projects and trades in the field of civil engineering
- To know the major phases of a construction project
- To acquire a general vision:
- of regulations
- of construction technologies and especially reinforced concrete of the principles of dimensioning
- To raise awareness of the problems of sustainable development in the context of the design and realisation of a work

Programme Description
- General Introduction
- The Project 's Actors
- Engineering
- Architect
- The project's times (the different stages of a project)
- Regulation (mainly of the building):
- Town planning
- Fire safety- PMR
- Earthquake
- DTU

- Fascicles...
- Construction technology: terraces, foundations, different structures, other bodies of state
- Descent of charges and contouring
- Current dimensions of works (buildings and works of art, such as bridges)
- Environmental quality and sustainable development in construction

Target generic centrale-specific field-related skills and knowledge
- Know all the time and actors of a project
- Know the regulatory constraints of a project
- Know how to size the main elements of the current works
- Know how to integrate the concept of sustainable development into a project

Knowledge Control Procedures
CC: Mini Project CR (100%)

Bibliography
- Polycopies of courses.
- Course materials.

Teacher
- Didier Bruneel (engineer, Bouches-du-Rhône department, Marseille)

Sustainable development objectives (SDO)
11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change

Distribution of hours
Total: 24
Magistrates: 12
Directed work: 12

Language(s) used during the course: French

MECA

MECA Project

Prerequisites: No

Learning Objectives

- Implement the different knowledge and skills learned during the course of the training, whether technical or organisational
- Know how to tackle a real problem and its different constraints
- Know how to supplement your knowledge and skills according to the needs of the project
- Work in teams and in interface with a proxy
- Structure your work in time
- Know how to report on your work

Programme Description

- Different subjects are proposed at the beginning of the year (mid-September) and treated each by a group of two to three students. These topics are of interest to the world of academic and/or industrial research.
- The supervision is provided by one or two teachers or collaborators.
- About half a day a week is dedicated to them.
- The work is carried out mainly in autonomy, and the students are responsible for contacting contacts to help them deal with the hard points.
- The project ends with a support and the delivery of a report (last fortnight of March).

Target generic centrale-specific field-related skills and knowledge

- Know how to tackle and break down a complex problem
- Know how to propose innovative solutions
- Know how to structure your work over time
- Know how to report on your work
- Know how to find an organisation within a group and in interface with external collaborators

Knowledge Control Procedures

- CC1: Support (50%)
- DC2: Report (50%)

Bibliography

Dependent on subject.

Teacher

- Mechanical

Teachers - Outside Industrial or University Research Executives

Distribution of hours

Total: 100

Projects: 100

Language(s) used during the course: French

MECA

Structure Optimisation

Prerequisites: No

Learning Objectives
- Acquire the theoretical basis needed to formulate a problem of optimisation in structural mechanics
- Know and know how to implement the major classes of design problems
- Through simple and academic examples
- Through a number of industrial applications by introducing yourself to professional optimisation software (OptiStruct)
- Discover the methods being developed in the field of optimisation

Programme Description
- Issues of structural optimisation
- Large problem classes
- Introduction to the basic theoretical notions of differential optimisation in finite dimension and algorithmic principles of numerical optimization
- Introduction to optimal control
- Parametric optimization
- Geometric optimization
- Topological optimisation (SIMP, homogenisation, penalisation)
- Getting started and parameterisation An industrial code (OptiStruct)
- Other methods (level lines, genetic algorithms...) and new trends

Target generic centrale-specific field-related skills and knowledge
- Knowing how to formulate an optimisation problem
- Knowing how to choose and implement the appropriate algorithm
- Knowing how to use and configure a calculation software for optimisation
- Knowing how to analyse and criticise the calculation results

Knowledge Control Procedures
- CC1: TP Report (40%)
- DS1: 2 h written evaluation (30%)
- DS2: 2 hour machine evaluation (30%)

Bibliography
Course materials in PDF.

Teacher

- Jean-Marie Rossi

Sustainable development objectives (SDO)

12-Responsible consumption and production

Distribution of hours

Total: 24
Magistrates: 16
Practical work: 8

Language(s) used during the course: French

MECA

Fast Dynamics and Crash

Prerequisites: No

Learning Objectives

Discover the specific problems related to the modelling of materials and structures in rapid dynamics and crash:
- Explicit integration patterns in time
- Geometric non-linearities (large rotations, large displacements)
- Non-linear behaviours of materials
- Contact-friction
- Specific finite elements
- Use and know how to set an explicit calculation code (Radioss)

Programme Description

- Introduction to Dynamic Mechanical Systems Analysis
- Presentation of the HyperWorks software suite
- Time Discretisation (implicit/explicit, stability condition of schemas)
- Spatial Discretisation (finite elements and hourglass control)
- Behavioural Relationships of Different Materials
- Contact Modelling
- Addition of kinematic Constraints and Loads
- Practising by Using 'a fast dynamic calculation code (HyperWorks/Radioss)
- Problem data
- Algorithm selection and setup
- Critical analysis of calculation results

Target generic centrale-specific field-related skills and knowledge

- Know the theoretical specificities of rapid dynamics
- Know how to choose the construction of a model adapted to the problem treated
- Know how to choose the algorithm adapted to the problem treated
- Know how to analyse and criticise a calculation result

Knowledge Control Procedures

CC: Mini Project CR (100%)

Teacher

- Pierre-Christophe Masson (engineer, Altair, Lyon)
- Mathis Loverini (engineer, Altair, Lyon)

Distribution of hours

Total: 24
Magistrates: 8
Directed work: 8
Practical work: 8

Language(s) used during the course: French

GREEN

Polyphasic reactions

Prerequisites:

Deep 2A Chemistry Process engineering

Learning Objectives

In the direction of the evolution towards a more "sustainable" chemistry, we will address some principles and applications of recent and industrialised methods of molecular transformations. These techniques are very often based on processes involving sophisticated materials or media. At the same time, we will present the preparation of these polyphasic media and their properties.
- To supplement the knowledge on the means to achieve organic synthesis reactions in the direction of evolution towards a more "sustainable" chemistry
- To know the current and industrialised methods that allow molecules to be produced in compliance with environmental
regulations- To understand the physico-chemical nature of the alternative media used, their contribution to organic synthesis

Programme Description

- Principles and functioning of polyphasic reactions and catalysts and properties of materials used (heterogeneous catalysis, supported catalysis, biphasic catalysis). Solid phase summaries. Supported
Chemistry - Acid or Basic
Solid Catalysts - Properties and Use of Alternative Solvents (CO_2 supercritical, fluorinated solvents, ionic liquids, water, biosolvents)
- Concept of Supramolecular
Chemistry- Transfer of Classic Phases or Involving Macromolecular
Receivers- Case Study on the Preparation of Polythene and Polypropylene by an INEOS

Target generic centrale-specific field-related skills and knowledge

- Ability to expand a tool or concept to other uses
- Ability to collect and analyse information with logic and method
- Ability to understand and formulate the problem (assumptions, orders of magnitude, etc.)
- Ability to recognise specific elements of a problem
- Ability to propose one or more resolution scenarios

Knowledge Control Procedures

ContinuousWritten: 75%TP
Report: 25%

Bibliography

Paper.

Teacher

- Damien Hérault
- Didier Nuel
- Intervener of the company INEOS

Sustainable development objectives (SDO)

12-Responsible consumption and production

Distribution of hours

Total: 25
Magistrates: 13
Directed work: 4
Practical work: 8

Language(s) used during the course: French

GREEN

Expertise in chemistry

Prerequisites:
Deep 2A Chemistry Process engineering

Learning Objectives
- Mastering specific techniques of working in chemistry laboratories
- Completing the mastery of laboratory techniques different from those seen in PRAT
- Use of conventional apparatus used in research or analysis laboratories
- Various purification methods based on the physico-chemical properties of molecules
- Risk management for the products used
- Working alone or in teams
- Preparation of technical reports

Programme Description
- Use of Schlenk techniques to work in a controlled atmosphere without air or water
- Handling of organometallic species sensitive to air and water
- Comparison of experimental parameters, in order to optimise reactions
- Method of addition of reagents allowing exothermal control
- Temperature control for better control of the selectivity of a reaction
- Use of vacuum distillation
- Use of sublimation
- Use of chromatography
- Analysis by nuclear magnetic resonance spectroscopy
- Analysis by thin-layer chromatography
- Analysis by gas chromatography

Target generic centrale-specific field-related skills and knowledge
These techniques are essential for the continuation of studies in the research laboratory and, in particular, in the course of a master's degree in chemistry, then in the context of a thesis in organic chemistry. Know and master advanced techniques used in organic synthesis.

Knowledge Control Procedures
Continuous monitoring, reporting: 100%

Teacher
- D. Hérault

Sustainable development objectives (SDO)
12-Responsible consumption and production

Distribution of hours
Total: 25
Practical work: 25

Language(s) used during the course French

PICSEL

Fundamentals of Photonics

Prerequisites:

Electromagnetism courses 1st cycle (Flat Waves, Polarisation...)

Learning Objectives

This EU is intended for students who wish to colour their training in the fields of optics, electromagnetism and photonics. It enables them to increase their knowledge of lasers, wave optics, non-linear optics and electromagnetism computation. There are many opportunities in both large groups and SMEs, for jobs ranging from offices to R&D, in the defence, aeronautics or biomedical sectors...

Programme Description

The teaching is partly common with the course "Advanced Electromagnetism - Part II" of the Master 2 EuroPhotonics and is divided into two main themes: (1) generation and (2) propagation of light

Generation:
This theme will be mainly devoted to the study of lasers, which is a pervasive instrument in the industry of the twenty-first century. The teaching will begin with the fundamental aspects of laser emission and will conclude with the intervention of industrialists (Thales, Leukos, Amplitude-Systems...) on the latest technical developments in power impulsive lasers or white supercontinuums... Other recent sources (nano-antennas, quantum boxes, nanodiamonds, fluorescent markers) useful in very varied fields such as Biomedical imaging, quantum cryptography or nanotechnology ... will also be studied.

Spreading Light:
This section will begin with a reminder of the fundamental concepts of wave optics (Interferometry, diffraction) and electromagnetism (planar waves, polarisation, dispersion and causality) in order to study more specific fields such as polarimetry, media (dielectric, chiral, conductive or magnetic) and non-linear optics.

Structure of teaching:
Courses/Ts will be supplemented by experimental TPs: Assembly and adjustment of an impulse laser, Generation of 2d harmonic, Study of a laser diode, Electro- or acousto-optical modulations, Polarisation and Spectroscopy.

Knowledge Control Procedures

CC1: 10%
DC2 UPS Optic: Laser1 15%
CC3: 15%
CC4 Nonlinear Optics: Laser2 10%
CC5: Electromagnetism 30%
TP: 20%

Bibliography

Bright Waves, Champeau (Optical).
Classic Electrodynamics, Jackson (Electromagnetism).
Electromagnetism, Pérez (Electromagnetism + simple than Jackson).
Non-linear optics, Sanchez (Non-linear optics).
Non-linear optics, Serge Huard (Poly 2000).

Teacher

- Laurent Gallais
- Jean Bittebierre
- Frédéric Lemarquis
- Nicolas Sandeau
- Miguel Alonso
- Frédéric Zolla
- Boris Gralak

Sustainable development objectives (SDO)

3-Access to Health
7-Use of renewable energy
13-Combating climate change

Distribution of hours

Total: 80
Magistrates: 62
Practical work: 16
Other: 2

Language(s) used during the course French

MECA

Linear Waves in Mechanics

Prerequisites: No

Learning Objectives

- Discover the wide range of common phenomena related to waves and vibrations
- Be able to understand the dynamic phenomena in mechanics (solids, fluids and acoustics)
- Know how to distinguish the notions of waves and vibration and know the dedicated formalisms - Master the basic theoretical tools related to these notions
- Know how to use digital tools to solve different types of problems

Programme Description

- Course Reminders and Introduction to Wave and Vibration Phenomena in Different Media
- Introduction of Time Dimension in MMC and Consequences
- Notion of Wave
- Formalism
- Different Types of Equations and Solutions
- Introduction of Limit Conditions
- Stationary Waves and Vibrations, Own Modes
- Tools and Methods
- Buckingham Pi Theorem and Applications
- Transformed from Fourier, TFD, Shannon criterion
- CFL
- Introduction to non-linear acoustics
- Constitutive equations in non-linear non-viscous case▪Constitutive equations in non-linear viscous case
- Applications of non-linear acoustics

Target generic centrale-specific field-related skills and knowledge

- Know how to model dynamic problems
- Know how to identify characteristic parameters of a problem
- Know how to define the methodology for solving a dynamic problem
- Know how to identify complex dynamic phenomena such as instability or chaos

Knowledge Control Procedures

CC1: TP Report (50%)
CC2: Scientific file (50%)

Bibliography

J. Billingham and A.C. King, *Wave Motion*, Cambridge University Press, 2001.
G.B. Whitham, *Linear and nonlinear waves*, Wiley, 1999.
J. Sirven, *Waves: Linear to Non-Linear*, Dunod, 1999.

Teacher

- Daniel Mazzoni
- Bruno Cochelin

Distribution of hours

Total: 24
Magistrates: 8
Directed work: 8
Practical work: 8

Language(s) used during the course French

PICSEL

Smarts Systems

Prerequisites: No

Learning Objectives
At the end of the course, students will have a good understanding of the fundamentals of intelligent systems and the possibilities offered by detection, communication, analysis and decision-making methods to create intelligent systems. Understanding technologies and mastering data processing techniques. Implementation of the lessons learned for a multidisciplinary project.

Programme Description
Intelligent systems are now part of our everyday lives, as evidenced by the existence of many applications that rely on artificial intelligence (AI) paradigms. Intelligent systems are systems that include processes, based on several theories to replicate some human behaviours, in order to perform a task or set of tasks. This unit aims to provide an overview and introduction to the growing and increasingly strategic area of intelligent systems integration. These systems become ubiquitous and can be present in all areas. This course will acquire the key fundamentals and technologies of intelligent systems and their integration. Intelligent systems combine the processing of often massive and/or heterogeneous data (Big Data) with detection, actuation and communication, and are able to analyse complex situations, make autonomous decisions and be predictive and secure.
The course will also describe the progress made in industry and academia using examples from various industrial sectors. The underlying techniques for such systems will be described in parallel with the processes used to create these technologies.

Target generic centrale-specific field-related skills and knowledge
- Learn to question the choice of methods
- Mastering the complexity of systems and associated problems
- Enrol in a strategic vision and know how to implement it
- Know how to run programmes
- Create value through scientific and technical innovation

Knowledge Control Procedures
Continuous monitoring: average reporting

Bibliography

Teacher

- Salah Bourennane
-Caroline Fossati
- Thierry Gaidon

Sustainable development objectives (SDO)

11-Sustainable cities and communities
12-Responsible consumption and production
13-Combating climate change
14-Aquatic Life
15-Earth Life

Distribution of hours

Total: 80
Magistrates: 60
Directed work: 10
Practical work: 10

Language(s) used during the course French

MECA

Material Behaviour

Prerequisites:

MMC, algebra and tensory analysis

Learning Objectives

- Exceeding the linear elasticity framework under the assumption of small disturbances
- Discover the main types of non-linear behaviour of materials
- Know the thermodynamic framework in which general models must register
- Master several patterns of behaviour
- Know how to deal with problems in large distortions
- Master the notions of configuration and measurement of stresses and distortions seen in the first year , adapted to the context of major distortions
- Knowing how to formulate laws of behaviour in large distortions
- Knowing how to implement these concepts in the framework of a computational software

Programme Description

Viscoplasticity and damage:
- Highlighting on simple tensile tests
- Thermodynamics of irreversible processes as frame for writing behaviour models
- Three examples of elasto (visco)
-plasticity models
- An example of elasticity-damage model Large distortions:
- Definition of kinematics and synthetic Large deformations
- Balance equations
- Rewriting of the thermodynamic frame in different configurations
- Non-linear elasticity
- Hyperelastic models, special cases of isotropy and incompressibility[1]
- Some examples of dissipative models, notions of intermediate states and application to elastomers

Target generic centrale-specific field-related skills and knowledge

- Know how to identify the right behaviour model for the problem being treated
- Modelling complex problems to advanced behaviour models
- Conduct and analyse large deformation calculations
- Propose behaviour models adapted to new materials

Knowledge Control Procedures

- DS1: 2h written evaluation on Part 1st (50%)
- DS2: 2h written evaluation on Part 2 (50%)

Bibliography

Copies and course materials in PDF for Part 2.
J. Garrigues, *Cinematics of Continuous Environments* (online).
J. Lemaître and J.-L. Chaboche, *Mechanics of Solid Materials*, 2004.
D. François, A. Pineau et A. Zaoui, *ÉLastiness and Plasticity*, 2009.
G. Holzapffel, *Nonlinear solid mechanics, 2000*.
C. Felippa, Nonlinear Finite Elements (online).

Teacher

- Thierry Désoyer
- Stéphane Lejeune

Sustainable development objectives (SDO)

9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours

Total: 48
Magistrates: 28
Directed work: 16
Practical work: 4

Language(s) used during the course: French

MECA

Thin, dynamic and unstable structures

Prerequisites:
MMC, linear elasticity.

Learning Objectives
- To acquire the knowledge necessary for the understanding of structure models (hypotheses and application framework), as well as the related sizing methods:
- To model and analyse beam and plate based structures
- To master the sizing methods in linear elasticity and in flare
- To acquire the fundamental notions around oscillations in continuous environments (solid and fluid) and to use them to solve problems
Industrial Problems:
- Knowing how to determine and exploit the clean modes of a linear continuous medium
- Knowing how to calculate vibratory levels for large-sized structures
- Knowing the main dynamic instabilities modes

Programme Description
Thin structures, flambement
- Three-dimensional elastodynamic reminders (kinematics, aesthetics, Hooke's law, local equations, integral formulations)
- Beam models:
- Hypotheses of Euler-Navier-Bernoulli and Timoshenko
- Model development - Energy theorems (Menabréa and Castigliano)
- Elasticity Dimensioning
- Model plates (Kirchoff-Love and Reissner-Mindlin)
- Instabilities of thin structures in compression under moderate rotations (Euler flare, von-Karmann model) Dynamic, vibrations, instabilities
- Clean modes: definition and application to cases of linear elastic solids, acoustic modes, fluid sloshing modes
- Forced responses: introduction of damping, calculation of forced responses, model reduction by truncation and substructuring
- Some practical problems: vibrations of rotors, dynamic absorbers.
- Dynamic instabilities induced by flows or friction: presentation of the mechanisms of divergence, flutter, gallop
- Non-linear vibrations: linearity limits, frequency-amplitude dependency, stability

Target generic centrale-specific field-related skills and knowledge
- Ability to model and analyse complex structures
- Ability to master sizing methods in elasticity and linear dynamics
- Ability to anticipate complex phenomena of instability
- Propose reduced approaches to minimise calculation costs

Knowledge Control Procedures

DS1: 2h written evaluation on Part 1st (50%)
CC: TP CR and MCQ for Part 2 (10%)
DS2: 2h written evaluation on Part 2 (40%)

Bibliography

Polycopies of courses in
PFP. Ballard and A. Millard, *Elastic beams and bows*, Édition École polytechnique, 2009.
C.R. Calladine, *Theory of shell structures*, Cambridge University Press, 1983.
M. Géradin and D. Rixen, *Théâtre Application to Structure Dynamics*, Masson, 1993.
M. Lalanne and G. Ferraris, *Rotordynamics Prediction in Engineering, 2nd ed., Wiley, 1998.*

Teacher

Stéphane
BourgeoisBruno
CochelinEmmanuelle Sarrouy

Sustainable development objectives (SDO)

9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours

Total: 48
Magistrates: 32
Directed work: 10
Directed work: 6

Language(s) used during the course:: French

MECA

Digital Mechanical Methods

Prerequisites:

Basic concepts in numerical analysis: interpolation, digital integration, basic discretisation methods (finite differences, finite elements, finite volumes)

Learning Objectives

- Raise awareness of the challenges of contemporary numerical simulation in terms of both the means of calculation and the specificities of the equations models encountered in fluids, solids or acoustics
- Link with general and basic concepts seen in mathematics from a theoretical point of view and apply them in the context of the business of mechanics
- Provide a global vision of the numerical methods used in mechanics (solid, fluid):
- be able to Basic computational code based on conventional discretisation methods (finite elements, finite volumes)
- be able to understand the specific methods encountered in computational codes for fluid and solid parameters

Programme Description

The specificities of the problems encountered in solid mechanics, fluid mechanics and acoustics will be emphasised and the different approaches used will be justified. The specifics of numerical simulations of nonlinear problems will be discussed. Difficulties associated with setting up industrial computing tools will be highlighted. Eight hours will be dedicated to an introduction to multiphysical software.

- General Considerations
- Current trends on the means of calculation, towards the massively parallel
- General principles of discretisation patterns in time and spaces, convergence-stability-consistency, implicit and explicit schemas
- General on finite differences, finite elements, spectral methods, finite volumes, edge elements
- Numerical methods in mechanics: an introduction to CFD
- Finite volume techniques and finite fluid elements
- The problem of fluid incompressibility- Application to the resolution of Navier-Stokes equations for an incompressible fluid
- Stabilised methods
- Simulation of fluid turbulence
- Towards an enlightened use of industrial fluid calculation codes: case Ansys-Fluent
- Numerical methods in mechanics: an introduction to the calculation of solids and structures
- Code finite elements, finite element techniques, algorithmic framework
- Beyond elasticity: time patterns, non-linear problems (no time, iterations), total Lagrangian approach- numerical methods in mechanics: An Introduction to Acoustics
- Finite Elements in Acoustics
- Methods to Integral Onboard
- From CAD to Computing: an integrated approach from design to simulation; application of the

isogeometric method to fluids and solids
- Practical applications under COMSOL Multiphysics: practical work on machines (8 hours)

Target generic centrale-specific field-related skills and knowledge

- Ability to take account of basic physical problems in the use of industrial calculation codes - Ability to construct new software solutions to simulate complex phenomena not present in standard industrial computing tools - Ability to understand a complex multi-physical situation in order to offer high-performance software solutions - Ability to take a step back from a rational use of tools

Knowledge Control Procedures

- CC: TP Report (50%)
- DS: 2 h written evaluation (50%)

Bibliography

Course materials in PDF.
T.J.R. Hughes, *The finite method element*, *eds. Prentice-Hall*, 1987.
A. Ibrahimbegovic, *Nonlinear solid mechanics*, Hermes, 2009.
J. Wendt, *Computational Fluid Dynamics*, Springer, 2009.

Teacher

- Dominique Eyheramendy
- Vacatee for TP

Sustainable development objectives (SDO)

9-Building Resilient Infrastructure

Distribution of hours

Total: 24
Magistrates: 10
Directed work: 6
Practical work: 8

Language(s) used during the cours: French

MECA

Composites and laminates

Prerequisites:
MMC, linear elasticity, beams and plates.

Learning Objectives
- Discover the different types of composite materials and their implementation
- Learn the methods of calculating composite
materials structures - Master the notion of anisotropy in linear
elasticity - Know how to replace a heterogeneous medium with an equivalent homogeneous medium (micro-macro approaches) in a modelling
approach - Master the concepts of modelling laminates (plate models)
- Know how to analyse the breakage criteria for heterogeneous materials

Programme Description
General on composite materials:
- Constituents: Inclusions, Fibres, Resins, Tissues
- Implementation: mouldings, pultrusion, centrifugation, filamentary winding
- Finished products: laminates, plates and beams sandwiches
Elastic behaviour of heterogeneous media:
- Notion of representative elemental volume (VER) and equivalentnhomogeneous behaviou
- Characterisation of the VER (random media, periodical) and anisotropic elasticity
- Methods of homogenisation (Voigt, Reuss, effective modules, periodic homogenisation, Hashin and Shtrickman estimates and terminals) and implementation in an EF code (Abaqus)
- Modes and criteria for breaking laminates (maximum stresses and distortions, Tsaï-Hill, Hoffman, Tsaï-Wu)
- Models of laminated plates and sandwiches
- Applications to the dimensioning of composite structures

Target generic centrale-specific field-related skills and knowledge
- Know a range of materials and their potentials for different applications
- Use heterogeneous material models
- Define simplified heterogeneous material models for efficient calculations
- Be able to propose innovative material models

Knowledge Control Procedures
DS: 2 h written evaluation (75%)
CC: TP report (25%)

Bibliography

Transparents of courses PDF.
M. Bornert, T. Bretheau and P. Gilormini, Homogenisation of Materials Mechanics, volumes 1 and 2, Hermès, 2001.
J.-M. Berthelot, *Composite Materials: mechanical behaviour and structural analysis*, Tec&Doc, 1999.
D. Gay, *Composite Materials*, Hermès, 1991.

Teacher

- Stéphane Bourgeois

Sustainable development objectives (SDO)

9-Building Resilient Infrastructure
11-Sustainable cities and communities

Distribution of hours

Total: 24
Magistrates: 16
Directed work: 4
Practical work: 4

Language(s) used during the course French

MECA

Maintenance of materials and structures

Prerequisites:
MMC, tensory algebra and analysis, elastoplastic behaviour, beam pattern.

Learning Objectives
- Discover the classical approaches to linear failure mechanics
- Discover the main characteristics of the phenomenon of fatigue of materials and structures on simplenexamples
- Know the classical approaches to fatigue called "uniaxial" and discover the current approaches to fatigue (multiaxial)
- Learn the concepts and methods of calculation allowing to size the structures with regard to the calculation at break and limit analysis

Programme Description
Part 1: Phenomena and Models
- Linear Mechanics of Breaking: validity area and standard problem
- Global approach to rupture: energy recovery rate and Griffith criterion
- Local approach to rupture: stress intensity factors and K1c criterion
- Comparison between the two classical linear mechanical approaches to failure
- Influence of loading path (monotone or cyclic) on break behaviour of solid structures: phenomenology and classification
- "uniaxial" fatigue with many cycles: Wöhler curve and Haigh diagram; Paris law - "uniaxial" fatigue with a small number of cycles (oligocyclic): Manson-Coffin's law
- Multi-axial tiredness with many cycles: Dang Van macroscopic criteria for Sines and

MacroPart 2: Dimensioning of structures
- Limit load concepts and plastic ruin mechanisms: Examples of a bar lattice and a torsional cylindrical shaft - Theory of Breaking Computation: notion of local stress resistance domain and static approach for the calculation of loads potentially supported by a structure
- Dual kinematic approach
- Notion of safety coefficient
- Application to beam structures, notion of bending plastic ball

Target generic centrale-specific field-related skills and knowledge
- Knowledge of the Breaking Mechanisms
- Knowledge of the Key Breaking Criteria
- Knowledge of the Mechanisms that Can Lead to the Breaking of a Particular System
- Knowledge of the Dimensioning of a Structure to the Breaking Hold

Knowledge Control Procedures
DS1: 1 hr written evaluation of Part 1st (50%)
DS2: 1h written evaluation on Part 2 (50%)

Bibliography

- J. Garrigues, *Cinematics of continuous media* (online).
- J. Lemaître and J.-L. Chaboche, *Mechanics of solid materials*, ed. Dunod, 2004.
- D. François, A. Pineau and A. Zaoui, *Viscoplasticity, Damage, Mechanics of Breaking, Mechanics of Contact*, ed. Lavoisier, 2009.
- J. Salençon, *Breakdown Calculation and Limit Analysis*, Presses de l'ENPC, 1983.

Teacher

- Thierry Désoyer
- Stéphane Bourgeois

Sustainable development objectives (SDO)

9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours

Total: 24
Magistrates: 18
Directed work: 6

Language(s) used during the course French

MECA

Diphasic media and fluid-solid interactions

Prerequisites:
Mechanics of continuous media, Mechanics of solids and/or Mechanics of fluids

Learning Objectives
- Understand and model solid/fluid interactions in natural or urban environments: porous media (including concrete, soils, rocks and granular media), open-surface runoff with erosion
- acquire the basic elements to address hydraulic risk, flood risk, and risk analyses associated with dams reservoirs and river protective
levees - Concepts on dams and levees concerning environmental impacts, renewable energies and impacts of climate change

Programme Description
- Mechanics of porous media (y/c concrete, soils, rocks and granular media): diphasic conservation equations, behavioural laws (Mohr-Coulomb rupture criteria, Cam-Clay type behaviour models, Hill instability criterion) and solid/fluid interaction (Darcy law, heat transport, Terzaghi effective stresses, internal erosion)
- diphasic flows, erosion and sedimentary transport: diphasic conservation equations and jumping equations, fluid mechanics elements (turbulence, roughness), external flow/porous medium interactions (mass exchange, movement quantity exchange, Brinkman's law, external erosion), free-surface flows, Navier-Stokes equations with erosion, Saint-Venant equations (shallow water eqs.) with erosion
- Application Examples: reservoir dams and river dikes for flood protection (utility, design, safety, water risk analysis, study of some historical breakdowns), environmental impact of reservoir dams and renewable energy, flood risk and climate
change
- TP1: Proomechanical calculation with Abaqus
- TP2: Simulation of the erosion rupture of a protective river dam and spread of the flood wave with CastorDigue

Target generic centrale-specific field-related skills and knowledge
- Understanding and knowing how to model porous environments, open-surface flows with erosion
- Know how to propose an operational model adapted to the problem
- Analyse and criticise the results of calculation
- Develop complex models of multiphase environments for a new problem

Knowledge Control Procedures
Practical Work Report: 100%

Teacher

- Stéphane Bonelli (Research Director, Inrae, Aix-en-Provence)

Distribution of hours

Total: 24
Magistrates: 12
Directed work: 4
Practical work: 8

Language(s) used during the course: French

GREEN

Green chemistry

Prerequisites:

KineticsChemical
thermodynamicsGeneral organic chemistry

Learning Objectives

- Be aware of the impact of organic chemistry on the environment.
- Be able to identify the different levels where the chemist can act to make the chemical synthesis greener.
- Master the metrics for green chemistry.
- Be able to design a safe and green chemistry synthetic pathway.
- Know alternative methods to carry out out environmentally friendly reactions.
- Know the usefulness of agricultural resources.
- Know how enzymes work and the potential use of biocatalysts in organic chemistry.

Programme Description

Chemistry plays a central role in the economic development of modern societies. There is a diverse range of chemicals that we use which make our lives better. However, there is a huge impact on the chemical industries on our ecosystem. In order to reduce demand on decreasing resources and to decrease waste, chemists have to design new processes. This module presents the development of new tools in order to make chemistry environment-friendly and safer. Green chemistry represents an important tool for the growth of sustainable development.

Theoretical aspects:
- The problem of sustainable development and chemistry
- Presentation of metrics for green chemistry (E Factor, atom economy...)
- The 12 principles of green chemistry
- Use of the biomass for the synthesis of chemicals, solvents, biofuels
- Biocatalysis (enzymatic kinetics, different types of enzymes)
- Biomimetic catalysis (catalysis in confined space, covalent systems, self-assembled systems, systems with a endohedral functionalisation)

Practical teaching:
- Green oxidation in organic chemistry

Knowledge Control Procedures

Written exam: 50%Continuous
Control (TP and MCQ): 50%

Bibliography

J. Augé and M.-C. Scherrmann, *Green Chemistry - Concepts and Applications*, 505 p., EDP Sciences, Current Knowledge Collection, 2016.

Teacher

- Bastien Chatelet
- Didier Nuel
- Damien Hérault

Sustainable development objectives (SDO)

12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 25
Magistrates: 13
Directed work: 4
Practical work: 8

Language(s) used during the course: French

DIGITAL

Customer Experience

Prerequisites: No

Learning Objectives

- Explore opportunities, confront hypotheses with a view to creating an offer or a product - in services
- Associate the customer, the user, the user in the different phases of construction, planning and execution of a project: analysis of the need, co-design, realisation of the V1 and process of

continuous improvementThe different concepts and methods will be seen mainly in the form of workshops, and associated techniques, such as Lean service, agility, or Obeya, will be worked on.

Programme Description

This EU includes:
- A module on customer need, the expression of this need (theory followed by a situation)
- A module on the Lean applied to engineering, upstream of production, and on the links between Lean and agility (theory, implementation, then construction of an Obeya)
- A module on agile project management (theory, then implementation) and the Design service
- A module on user experience (Ux Design)
- A module on the user interface (Ui Design)
- A module on the no-code/low-code
- A module on collective intelligence and the creative team work
- Several conferences according to the current topics related to the EU...
- A cross-cutting project to be conducted that will link with all the modules of the courses

Target generic centrale-specific field-related skills and knowledge

- C1: Identification of innovations in terms of capturing and analysing customer needs, their usefulness, the points of vigilance and definition of actions favouring the optimisation of customer satisfaction
- C3: Implementation of mini-projects with technical aspects (needs analysis, design, planning, and project monitoring) and organisational aspects (stakeholders, organisation, communication), understanding of new agile-type project management methods
- C4: all aspects of team management (role of production actors, conflict management and coordination of actors)
- C5: define a localised strategy and control its operational decline to improve the efficiency of the customer experience

Knowledge Control Procedures

- Need expression - rendering and continuous monitoring: 25%
- Lean engineering - continuous rendering and control: 25%
- Agile Project Management - Continuous Control: 15%
- Collective Intelligence: 10%
- Ui - Continuous Control: 10%
- Ux - Continuous Control: 10%
- Conferences - Presence: 5%

Bibliography

Body, L., and Tallec, C. (2015), *L'Experience client*, Eyrolles.
Barbaray, C. (2016), *Satisfaction, loyalty and customer experience*, Dunod.
Gaudichau, O, Matsumoto, E and Magnani, F (2) 019), *Lean at 540°*, AFNIL.

Teacher

- F. Magnani (ECM)
- F. Brucker (ECM)
- Mr. Lesbros (lawyer)
- C. Morin (free lance)
- S. Olivencia (Excilys)
- V. Ly (free lance)
- Mr. Heredero (Ouishare)

Sustainable development objectives (SDO)

4-Access to quality education
8-Access to decent jobs
9-Building Resilient Infrastructure
12-Responsible consumption and production

Distribution of hours

Total: 100
Magistrates: 83
Directed work: 17

Language(s) used during the course: French

COMMON TRUNK

Engineer to address strategy and innovation challenges

Prerequisites: No

Learning Objectives

- Become familiar with the strategic é of companies
 - î sort out the first é é of the vocabulary "managementé rial and manager" - î sort out the bote tools, concepts and mthodes essential of the stratgie
- é develop the capacitative values of rflexion on management
 issues- Understand and solve small stratton cases Corporate
 governance - Dployer une culture glmprov nconvenale en matire de gestion pour savoir le monde socio-économique

 - Act as a responsible player by becoming aware of CSR

Programme Description

- Session 1: Introduction à Enterprise é
- Session 2: Segmentation and Key Success Factors
- Session 3: Competitive Environments
- Session 4: The business model canva
- Session 5: The portfolio of activities é

Target generic centrale-specific field-related skills and knowledge

C5 - Strategic Vision: components 1, 2 and 3

Knowledge Control Procedures

Individual quiz on mastering business fundamentals: 40% Case
Study & Presentation on Understanding a Business Environment and Critical Analysis of Complex Business Situations: 60%

Bibliography

P. Chereau, P-X Meschi, *The Strategic é for Business* (Pearson, 2014).
David Collis and Cynthia Montgomery, *Corporate Strategy - A Resource-Based Approach* (McGraw-Hill, 1998).
Pankaj Ghemawat, *Strategy and the Business Landscape* (Prentice Hall, 2009).Gerry Johnson, Kevan Scholes, Richard Whittington, Fré dé ric Fré ry, *Strategic* (Pearson Education, 2008).
Lehmann-Ortega, Leroy, Garrette, Dussauge, Durand, *Strategor, (od, 2013).*
M. E. Porter (1982), Strategic é and Competition: *Industry Sector and Competition Analysis Technique*, Economica.
M. E. Porter, (1986), *Competitive Advantage: how to get ahead of competitors and keep ahead*, InterEditions.
Read é specific rules é cialisé s: *Le Monde* (daily), *Les Échos* (daily), *L'Essentiel du management* (monthly), *Capital* (monthly), *La revue française de gestion*.

Teacher

- Annelise MATHIEU

Distribution of hours

Total: 10
Magistrates: 10

Language(s) used during the course: French

COMMON TRUNK

Engineer to face the challenges of strategy, innovation and development of innovation and intrapreneurship
business management

Learning Objectives
î the fundamentals of intrapreneurship

Programme Description
(2 hours per session)
Session 1 - Innovating with Intrapreneurship: description of the 4 main streams of entrepreneurship (é cole é economics, é cole des traits, é process school, and é school of entrepreneurial organisation), various forms of entrepreneurship, and é finishes of intrapreneurship/case study
Session 2 - Building an Intrapreneurial Project: development of the é, formulation of the intrapreneurial intention, development é business plan, and search for sponsors/case studies
Session 3 - Become an Intrapreneur: identification of the intrapreneurial traits of the organisation's employees, and distinction between the intrapreneur and the traditional manager à the entrepreneur/case study
Session 4 - Conduct an Intrapreneurial Project: overview of the working methods à the start-up mind (agilité, lean start-up, scrum, design thinking), and their tools/case studies
Session 5 - Intratake according to é strategy: analysis of the organisation'à tools for é strategic renewal é intrapreneurship, and é understanding of é strategic balances é case study

Generic Central Skills & Knowledge Target:
C1 - Innovation: central é ingers é value through scientific and technical innovation.
C2 - Complexité: the central engineer é mastered the complexity é the systems è and the problems é he encountered.
C5 - Strategic é: the central engineer is part of a strategic vision and knows how to implement it

Knowledge Control Procedures
Case study - 5 h: 40%
Individual final exam - 1h: 60%

Bibliography

Lhemann-Ortega L., Leroy F., Garette B., Dussauge P., Durand R., *Strategor, Dunod, 2013.*
Loilier T., Tellier A., *Les Grands Auteurs en stratgie, Éditions EMS Management et socié té, 2007.*
Messeghem K., Torres O., *Les Grands Auteurs en entrepreneurship et PME, Éditions EMS Management et socié té, 2015.*
Pinchot G., *Intrapreneuring, Harper and Row, 1985.*

Teacher

- Melanie ROUX

Distribution of hours

Total: 10
Magistrates: 10

Language(s) used during the course: French

COMMON TRUNK

Engineer to face the challenges of strategy, innovation and business developmentSustainable growth and value creation

Learning Objectives

Business acumen Paradoxes
Measuring risk
Creation Value
Traditional Value Creating Strategies
Building its Bubble of Excellence to help rejuvenate the Business model

Programme Description

Session 1	Firm's Objectives - Strategy and Value - Dream and Deliver: Paradox #1 Key learning: Value is about making the market Dream and delivering Results trust is essential.
Session 2	How to Create Value - Business Risk and WACC - Risk, Return and ROCE - Profitable Growth: Paradox #2 Key learning: You create value if you beat the Cost of Capital, if your ROCE is higher than the WACC
Session 3	Why Creating Value - The 6 reasons to create value - ROCE and Net Working Capital Key learning: Creating value is not a financial matter, it is about day-to-day life. Net Working Capital is a ROCE killer
Session 4	Strategies to Increase the Excess Return - Traditional Value Creating Strategies - Creating value through flexibility Key learning: Traditional value creating strategies relates to Growth and Excess Return

Session 5	Business Model Sustainability - Business Model community - Executing-Rejuvenating: Paradox #3 - Riding the business maturity curve and exiting Key learning: You have to build a Bubble of Excellence to Rejuvenate your business model

Generic Central Skills and Knowledge

C1 - Innovation: Creating Value through Scientific and Technical Innovation - Component 3
C2 - Complexity: Control the complexity of systems and issues - component 3
C5 - Strategic Vision - Component 3

Knowledge Control Procedures

Business
Weighted average market to book in the valueplus simulation: 100%

Teacher

- Olivier TABATONI

Distribution of hours

Total: 20
Magistrates: 10

Language(s) used during the course: English

COMMON TRUNK

The Engineer in the Face of Ethical and Human Issues

Programme Description:

Given the influence of business operations on contemporary social, environmental and democratic issues, it is important to understand the issues of corporate responsibility.
The first is to revisit the main theoretical, positive and normative approaches developed over half a century, with particular emphasis on the complex interactions between strategy, public opinion and public regulation.
On the other hand, on an empirical level, the way in which certain companies are addressing these issues will be studied from concrete situations.

Generic Central Skills & Knowledge Target:

C4 - Management of Men
C5 - Strategic Vision

Knowledge Control Procedures

Written evaluation (4 pages): critical analysis of a company's liability policy based on a practical case

Teacher

- Guillaume QUIQUEREZ

Distribution of hours

Total: 8
Magistrates: 8

Language(s) used during the course: English

COMMON TRUNK

Engineer on Ethical and Human IssuesConscious Leadership and Liberated Organisations

Learning Objectives

- Understand the importance of leadership as a key factor in the success of individuals, teams and organisations
- Be aware of the necessary alignment between our value system and our professional commitment
- Develop the ability to formulate one's own vision, mission, values and specific personality strengths
- Understand the vision of leadership that underpins the organisational logic of liberated enterprises
- Master the main approaches to recruitment and develop personal branding

Programme Description

Session 1 - Trust... the foundation of leadership? : 4
- What behaviours create trust?
- Definitions... what is leadership?
- "Conscious" leaders
- Work your inner state: inner game - outer game
- The circle of success
- Leadership models

Session 2 - Ethics, Values and Culture of Released Organisations: 4
- Leaders or "intrapreneurs"?
- Key tools of a liberated organisation
- Session 3 - Job market & personal branding: 4hr
- Recruitment from the employer side (assessment by skills, assessment of personality profiles)
- Recruitment from the candidate side: personal branding and self-knowledge

Generic Central Skills and Knowledge

C4 - Management of Men: components 1 and 2 "know, build" and "generate individual and collective performance" (competent level)
C5 - Strategic Vision: components 1 "anticipate and engage" (levels n/i/c) and 2 "make sense" (levels i/c)

Knowledge Control Procedures

3 individual quizzes on leadership fundamentals, liberated organisations and personal branding: 75%
Harvard business review case study + collective presentation of the "for" and "against" arguments: 25%

Bibliography

Robert DILTS, Conscious Leadership & Resilience
Frédéric LALOUX, Reinventing Organisations

Teacher

- Christophe DELABROYE

Distribution of hours

Total: 12
Magistrates: 12

Language(s) used during the course: English