SYLLABUS

2021/2022

Centrale Marseille

Semester 7

Contents

Training....13
Prerequisites:....13
Learning Objectives....13
Description of the programme....13
Target generic centrale-specific field-related skills and knowledge....13
Knowledge Control Procedures....13
Bibliography....14
Teacher....14
Sustainable development objectives (SDO)....14
Distribution of hours....14
Language(s) used during the course:....14
Elective modules....15
Menu 2 - Thermomechanical Continuous Media (THMC)....15
Prerequisites....15
Learning Objectives....15
Description of the programme....15
Target generic centrale-specific field-related skills and knowledge....16
Knowledge Control Procedures....16
Bibliography....16
Teacher....16
Distribution of hours....16
Language(s) used during the course:....16
Elective modules....17
Menu 2 - Electric Energy for Sustainable Development (E2D2)....17
Prerequisites....17
Learning Objectives....17
Description of the programme....17
Knowledge Control Procedures....18
Bibliography....18
Teacher....18
Distribution of hours....18
Language(s) used during the course:....18
Alternating Skills....19

Prerequisites 19
Learning Objectives 19
Description of the programme 19
Target generic centrale-specific field-related skills and knowledge 19
Knowledge Control Procedures 19
Bibliography 20
Teacher 20
Distribution of hours 20
Language(s) used during the course: 20
Elective modules 21
Menu 1 - Object Schedule 21
Prerequisites 21
Learning Objectives 21
Description of the programme 21
Target generic centrale-specific field-related skills and knowledge 21
Knowledge Control Procedures 21
Bibliography 21
Teacher 22
Distribution of hours 22
Language(s) used during the course: 22
Elective modules 23
Menu 2 - Artificial Intelligence and Games 23
Prerequisites 23
Learning Objectives 23
Description of the programme 23
Target generic centrale-specific field-related skills and knowledge 23
Knowledge Control Procedures 24
Bibliography 24
Teacher 24
Distribution of hours 24
Language(s) used during the course: 24
Elective modules 25
Menu 1 - Experimental and/or digital projects in the field of photonics 25
Prerequisites 25
Learning Objectives 25
Description of the programme 25

Knowledge Control Procedures 26
Bibliography 26
Teacher 26
Sustainable development objectives (SDO) 26
Distribution of hours 26
Language(s) used during the course: 26
Elective modules 27
Menu 2 - Energy & Environment 27
Prerequisites 27
Learning Objectives 27
Description of the programme 27
Target generic centrale-spécific field-related skills and knowledge 27
Knowledge Control Procedures 27
Bibliography 28
Teacher 28
Sustainable development objectives (SDO) 28
Distribution of hours 28
Language(s) used during the course: 28
Elective modules 29
Menu 3 - Economic philosophy 29
Prerequisites 29
Learning Objectives 29
Description of the programme 29
Target generic centrale-specific field-related skills and knowledge 29
Knowledge Control Procedures 30
Bibliography 30
Teacher 30
Sustainable development objectives (SDO) 30
Distribution of hours 30
Language(s) used during the course: 30
Elective modules 31
Menu 2 - General Culture 31
Prerequisites 31
Learning Objectives 31
Description of the programme 31
Target generic centrale-specific field-related skills and knowledge 31

Knowledge Control Procedures....31
Bibliography....31
Teacher....31
Sustainable development objectives (SDO)....32
Distribution of hours....32
Language(s) used during the course:....32
Elective modules....33
Menu 1 - Law and Sociology of Organisations....33
Prerequisites:....33
Learning Objectives....33
Programme Description....33
Target generic centrale-specific field-related skills and knowledge....34
Knowledge Control Procedures....34
Bibliography....34
Teacher....34
Distribution of hours....34
Language(s) used during the course:....34
Common Trunk....35
Social Sciences....35
Prerequisites....35
Learning Objectives....35
Description of the programme....35
Target generic centrale-specific field-related skills and knowledge....35
Knowledge Control Procedures....36
Bibliography....36
Teacher....36
Sustainable development objectives (SDO)....36
Distribution of hours....36
Language(s) used during the course:....36
Common Trunk....37
Deepening Chemistry - Process Engineering....37
Prerequisites....37
Learning Objectives....37
Description of the programme....37
Target generic centrale-specific field-related skills and knowledge....38
Knowledge Control Procedures....38

Bibliography 38
Teacher 38
Sustainable development objectives (SDO) 39
Distribution of hours 39
Course languages 39
Elective modules 40
Menu 3 - Remote sensing and applications 40
Prerequisites 40
Learning Objectives 40
Description of the programme 40
Target generic centrale-specific field-related skills and knowledge 40
Knowledge Control Procedures 40
Bibliography 40
Teacher 40
Distribution of hours 40
Language(s) used during the course: 40
Elective modules 41
Menu 1 - Macroeconomics and Economic Policy 41
Prerequisites 41
Learning Objectives 41
Description of the programme 41
Target generic centrale-specific field-related skills and knowledge 41
Knowledge Control Procedures 41
Bibliography 41
Teacher 42
Sustainable development objectives (SDO) 42
Distribution of hours 42
Language(s) used during the course: 42
Common Trunk 43
International Languages and Cultures 43
Prerequisites 43
Learning Objectives 43
Programme Description: 43
Generic Central Skills and Knowledge in the discipline: 43
Knowledge Control Procedures 44
Bibliography 44

Teacher 44
Sustainable development objectives (SDO) 44
Distribution of hours 44
Language(s) used during the course: 44
Elective modules 45
Menu 1 - Applied Mechanics - Flight Structures, Aerodynamics and Mechanics 45
Prerequisites 45
Learning Objectives 45
Description of the programme 45
Target generic centrale-specific field-related skills and knowledge 46
Knowledge Control Procedures 46
Bibliography 46
Teacher 46
Sustainable development objectives (SDO) 46
Distribution of hours 46
Language(s) used during the course: French 46
Elective modules 47
Menu 3 - Hyperfrequencies and Radio Frequencies 47
Prerequisite 47
Learning objectives 47
Description of the programme 47
Target generic centrale-specific field-related skills and knowledge 47
Knowledge Control Procedures 48
Bibliography 48
Teacher 48
Sustainable development objectives (SDO) 48
Distribution of hours 48
Language(s) used during the course: French 48
Elective modules 49
Menu 2 - Material Radiation Interaction 49
Prerequisites 49
Learning Objectives 49
Description of the programme 49
Target generic centrale-specific field-related skills and knowledge 50
Knowledge Control Procedures 50
Bibliography 50

Teacher 50
Sustainable development objectives (SDO) 50
Distribution of hours 50
Language(s) used during the course: 50
Elective modules 51
Menu 2 - Challenges of Modern Chemistry 51
Prerequisites 51
Learning Objectives 51
Description of the programme 51
Target generic centrale-specific field-related skills and knowledge 51
Knowledge Control Procedures 51
Bibliography 51
Teaching team: 52
Sustainable development objectives (SDO) 52
Distribution of hours 52
Language(s) used during the course: 52
Elective modules 53
Menu 3 - RIS 53
Prerequisites 53
Learning Objectives 53
Programme Description 53
Target generic centrale-specific field-related skills and knowledge 53
Knowledge Control Procedures 53
Bibliography 54
Teacher 54
Sustainable development objectives (SDO) 54
Distribution of hours 54
Course languages: 54
Common Trunk 55
Electronics Automatic Electrical Energy 55
Prerequisites 55
Learning Objectives 55
Description of the programme 55
Target generic centrale-specific field-related skills and knowledge 56
Knowledge Control Procedures 56
Bibliography 56

Teacher 57
Sustainable development objectives (SDO) 57
Distribution of hours 57
Language(s) used during the course: 57
Elective modules 58
Menu 3 - Continuous Media Dynamics 58
Prerequisite 58
Learning Objectives 58
Description of the programme 58
Target generic centrale-specific field-related skills and knowledge 59
Knowledge Control Procedures 59
Bibliography 59
Teacher 59
Sustainable development objectives (SDO) 59
Distribution of hours 59
Language(s) used during the course: French 59
Elective modules 60
Menu 3 - Web Development 60
Prerequisites 60
Learning Objectives 60
Description of the programme 60
Target generic centrale-specific field-related skills and knowledge 60
Knowledge Control Procedures 60
Bibliography 60
Teacher 60
Sustainable development objectives (SDO) 60
Distribution of hours 60
Language(s) used during the course: 60
Elective modules 61
Menu 3 - Computer Theory 61
Prerequisites 61
Learning Objectives 61
Description of the programme 61
Target generic centrale-specific field-related skills and knowledge 61
Knowledge Control Procedures: 61
Teacher 61

Sustainable development objectives (SDO) 61
Distribution of hours 61
Language(s) used during the course: 61
Elective modules 62
Menu 3 - Sensors, principles and implementation 62
Prerequisites 62
Learning Objectives 62
Description of the programme 62
Target generic centrale-specific field-related skills and knowledge 62
Knowledge Control Procedures 62
Bibliography 62
Teacher 62
Sustainable development objectives (SDO) 63
Distribution of hours 63
Language(s) used during the course: 63
Elective modules 64
Menu 2 - Digital servo 64
Prerequisites 64
Learning Objectives 64
Description of the programme 64
Target generic centrale-specific field-related skills and knowledge 64
Knowledge Control Procedures 64
Bibliography: 65
Teaching team: 65
Sustainable development objectives (SDO) 65
Distribution of hours 65
Language(s) used during the course: 65
Training 66
Prerequisites 66
Learning Objectives 66
Description of the programme 66
Target generic centrale-specific field-related skills and knowledge 66
Knowledge Control Procedures 66
Bibliography 67
Teacher 67
Distribution of hours 67

Language(s) used during the course: French 67
Elective modules 68
Menu 2 - Analysis and processing of biomedical signals 68
Prerequisites 68
Learning Objectives 68
Description of the programme 68
Target generic centrale-specific field-related skills and knowledge 68
Knowledge Control Procedures 68
Bibliography 68
Teacher 69
Sustainable development objectives (SDO) 69
Distribution of hours 69
Language(s) used during the course: 69
Common Trunk 70
Deepening Mathematics, Computing and Economics 70
Prerequisites 70
Learning Objectives 70
Description of the programme 70
Knowledge Control Procedures 70
Teacher 70
Distribution of hours 71
Language(s) used during the course: 71
Elective modules 72
Menu 1 - Telecommunications 72
Prerequisites 72
Learning Objectives 72
Programme Description 72
Target generic centrale-specific field-related skills and knowledge 72
Knowledge Control Procedures 72
Bibliography 72
Teacher 73
Sustainable development objectives (SDO) 73
Distribution of hours 73
Language(s) used during the course: French 73
Elective modules 74
Menu 2 - Introduction to stochastic processes 74

Prerequisite 74
Learning Objectives 74
Description of the programme 74
Target generic centrale-specific field-related skills and knowledge 74
Knowledge Control Procedures 75
Bibliography 75
Teacher 75
Distribution of hours 75
Language(s) used during the course: 75
Common Trunk 76
Mecha-Physical Deepening 76
Prerequisite 76
Learning Objectives 76
Description of the programme 76
Target generic centrale-specific field-related skills and knowledge 77
Knowledge Control Procedures 77
Bibliography 77
Teacher 77
Distribution of hours 78
Language(s) used during the course: 78
Elective modules 79
Menu 3 - Semi-Conductor Materials, Properties and Applications 79
Prerequisites 79
Learning Objectives 79
Description of the programme 79
Target generic centrale-specific field-related skills and knowledge 79
Knowledge Control Procedures 79
Bibliography 80
Teaching team: 80
Sustainable development objectives (SDO) 80
Distribution of hours 80
Language(s) used during the course: 80
Common Trunk 81
Thematic project 81
Prerequisites 81
Learning Objectives 81

Description of the programme 81
Target generic centrale-specific field-related skills and knowledge 82
Knowledge Control Procedures 82
Bibliography 82
Teaching team: 82
Sustainable development objectives (SDO) 82
Distribution of hours 82
Language(s) used during the course: 82
Elective modules 83
Menu 3 - Microcontrollers and their environment 83
Prerequisites 83
Learning Objectives 83
Description of the programme 83
Target generic centrale-specific field-related skills and knowledge 83
Knowledge Control Procedures 84
Bibliography 84
Teacher 84
Sustainable development objectives (SDO) 84
Distribution of hours 84
Language(s) used during the course: 84

Training

Prerequisites: No

Learning Objectives

The Train'ing is a place dedicated to the integration of the skills of the Central Engineer with 3 main axes: scientific openness, societal and cultural openness, professional openness.
- Understanding the different types of leadership
- Understanding the challenges of team
management- Awareness of societal and scientific
challenges-Capitalising on professional immersion (occupational health and safety, skills acquired in a professional environment...)

Description of the programme

With regard to scientific openness, scientific activities are proposed in relation to the components of the skills C1 (Scientific and Technical Innovation) and C2 (Control of Complexity and Systems). These activities are organised over 3 days (24 h. student) around a theme by articulating different learning formats (practical work, experience, visit, project, workshops, etc.).
The business opening includes workshops for learning and practising soft skills (Leadership and team management) as well as weeks dedicated to specific activities of the innovation project (ideation week and model week) evaluated by a jury.
Finally, the cultural and societal opening allows students to open up to disciplines such as the humanities, the arts and various fields of the social sciences in order to develop their capacity to take ownership of other languages, encourage their curiosity and creativity.
On the other hand, these training actions promote students' awareness of major social and environmental issues. In line with the institution's strategic directions, the proposed themes are based on the SDGs.
These different strands are addressed through choice of electives spread over the semester

Target generic centrale-specific field-related skills and knowledge

The Train'Ing is a privileged place to learn skills. The 5 core competencies are therefore addressed in Train'Ing.
- C1 (Scientific and Technical Innovation)
- C2 (Control of Complexity and Systems)
- C3 (Programme Direction)
- C4 (Human Management)
- C5 (Strategic Vision)

Knowledge Control Procedures

The various training actions of the three above-mentioned components are evaluated in continuous monitoring. Each week is evaluated. The offer of cultural and societal openness is assessed both by the presence of a minimum number of actions defined at the beginning of the year and by the rendering of reports.

Bibliography
Coming

Teacher
C. Delabroye, E. Sarrouy, P. Denis, J. Bittebierre, L. Gallais, F. Schwander, A. Martinez, C. Jazzar, B. Chatelet, N. Sandeau, P. Guichardon, F. Anselmet, O. Boiron, T. Durt, F. Lemarquis, I. de Riggi, D. Hérault Schiltz, P. Massart.

Sustainable development objectives (SDO)
3-Access to Health
5-Gender equality
7-Use of renewable energy
12-Responsible consumption and production
13-Combating climate change

Distribution of hours
Total: 104
Directed work: 24
Practical work: 56
Projects: 24

Language(s) used during the course: French

Elective modules

Menu 2 - Thermomechanical Continuous Media (THMC)

Prerequisites: No

Learning Objectives

The course is divided into two distinct parts:

1st part: Mechanics of compressible fluids

- Gain the knowledge necessary to understand compressible flows

- Know the theoretical bases of compressible aerodynamics

- Understand the main mechanisms induced by the effects of compressibility

- Know how to calculate the characteristics of straight or oblique shock waves

- Know how to calculate flows in Laval nozzles

2 pipes Part: Thermomechanical behaviours of solid materials

- Understanding the major types of solid behaviours

- Understanding the Thermodynamic Framework Underlying any behaviour model

- Using the Most Common Models

Description of the programme

1st part: Mechanics of compressible fluids

- General introduction - Examples of manifestations of compressibility in aeronautics/space
- Fluid mechanical reminders

- Effects of compressibility

- Mach waves- Conservation of energy – Saint-Venant equations

- Application to the study of the Laval nozzle

- Right shock

- Oblique shock and curved shock

- Relaxation of Meyer-Prandtl

Part 2: Thermomechanical behaviors of solid materials
- Thermoelasticity
- Thermoviscoelasticity
- Self-heating
- Elastoplasticity
- Metal shaping

Target generic centrale-specific field-related skills and knowledge
- Understanding the basics of compressible fluid mechanics (C2)
- Understanding the effects of compressibility, especially in aeronautics and thermopropulsion (C2)
- Knowing how to calculate shock wave characteristics (C2)
- Understanding the basics of solid thermomechanics (C2)
- Knowing the main thermomechanical behaviours of solids (C2)

Knowledge Control Procedures
- DS = written evaluation of 2 ×1 h (85%)
- CC = a practical work CR: (15%)

Bibliography
Kundu, P.K., and Cohen I.M., *Fluid mechanics*, 4th edition, Elsevier, 2010.
Carscallen, W.E, et al., *Introduction to compressible fluid flow*, CRC Press, 2014.
Lemaître, J., et al., . *Mechanics of solid materials*, ed. Dunod, 2009.

Teacher
- Olivier Boiron
- Thierry Désoyer
- Dominique Eyheramendy
- Yannick Knapp

Distribution of hours
Total: 30
Magistrates: 16
Directed work: 12
Practical work: 2

Language(s) used during the course: French

Elective modules

Menu 2 - Electric Energy for Sustainable Development (E2D2)

Prerequisites: No

Learning Objectives

- Analyse single-phase and three-phase, balanced and unbalanced
electrical circuits- Understand the functioning and characteristic mechanisms of the components of power-switching
electronics- Gain the basis for understanding electrical and electromechanical
energy conversion systems- Gain general knowledge about the operation and use of electromechanical converters (rotating machines)
- the basic properties of the three types of electrical machines (continuous, alternative and step-by-step)
- To enable students to understand the development, structure and various functions of the sensors and actuators of the electrical energy conversion systems and their electronic
power supply- To enable students to understand the development, structure and various functions constituting the electrical and electromechanical energy conversion systems

Description of the programme

Electric circuits (2 h)Electric power distribution
networks, equivalent circuits, power factor, power factor increase, balanced and unbalanced systems, definitions and

power calculation and measurement Static conversion of electric energy (10 h)
- Single phase transformer: equivalent electrical diagram and determination of elements, load transformer, energy balance, power factor bearing
- Power electronics: power electronics principles, different types of electric energy conversion, power electronics components, basic AC-DC converters, DC-DC converters (Buck and Boost), power electronics applications in industrial and

human industries Electromechanical conversion (10h)
- Electrical, magnetic and mechanical energies, power calculation and torque
- Machine DC: different types of excitation, operating equations, characteristics, energy balance, variable speed drive, universal
motor - Asynchronous machine (MAS): creation of the rotating field, technological aspects, operating principle, equivalent single phase diagram, determination of equivalent model elements, characteristics of the three phase asynchronous engine, torque, energy balance, variable
frequency power supply - Synchronous machine (MS): constitution, technological aspects, principle of operation, description of synchronous machines, power and torque calculation,

variable
frequency power supply - Step-by-step engine: principle of operation, different types of stepper engines and their control modes, static and dynamic behaviour, areas of use Directed work: (4 h)
Two 2 h sessions

Practical work: (4 h):
A session of Practical Work: 4h:
Simulation of DC/DC Buck converter-powered DC/DC machine using Matlab-Simulink

Target generic centrale-specific field-related skills and knowledge

- Ability to conduct "system"
-type thinking - Understanding the operation of the main elements of an electrical network- Ability to identify elements necessary for the understanding of the electrical energy conversion systems -Ability to understand the basic principles and purpose of power electronics, study and analysis of Buck DC/DC converters, Boost and Uncontrolled single-phase AC/DC weavers - Understanding the operation of the main components of an electric motor (example: Electric traction)
- Ability to understand all the scientific and technical dimensions of all the elements of an electric and electromechanical energy conversion chain from a specification

Knowledge Control Procedures

2h rating

Bibliography

- Copies of courses and practical works:
- Copy of course slides

Teacher

- Mohamed Boussak

Distribution of hours

Total: 30
Magistrates: 22
Directed work: 4
Practical work: 4

Language(s) used during the course: French

Alternating Skills

Prerequisites: No

Learning Objectives

The module "Skills in Alternation" aims to train alternates in a specific mission, either in a company, in a laboratory, in entrepreneurship or in an associative type. Alternatives are followed during periods of alternation by a "professional tutor" (company, laboratory, entrepreneurship, associative) and a "school tutor". The objective is to familiarise oneself with a particular environment, to acquire the codes there, to understand how the structure works, to develop innovative solutions to allow the project to progress.

Description of the programme

After having found a mission in a company, in a laboratory, in entrepreneurship or in an associative project, the alternator must make every effort to understand and understand the environment in which he is working, to clearly define his mission, his role, and to identify his interlocutors. He must also make regular points with his "tutor school", to keep him informed of his mission and his evolution. The module ends with two evaluations, an assessment of the school through a defence and an evaluation of the "business tutor.
The important points are:
- Training (basic knowledge, acquisition skills, sense of analysis, sense of synthesis, creativity and level of innovation)
- Work and results (quality level, quantity, effectiveness, achievement of objectives - Personality (initiative, sociability, contacts, interests, motivation, sense of responsibility, method and organisation, communication, openness, judgement and realism),
-

Target generic centrale-specific field-related skills and knowledge

The defence of semester 7 is collective, it lasts 15 minutes in January, and covers:
- (for new entrants) presentation context, issues and objectives;
- evolution of the mission;
- value added for the company;
- SWOT, risk analysis.

Knowledge Control Procedures

The module consists of a group of five to six alternates and an assessment of the "professional tutor".
Both assessments are in the form of a letter (A: Excellent, B: All right, C: Good, D: Pretty good, E: Fair, F: Failure).
The final evaluation is done by means of the two evaluations, when the average is difficult (A and B, for example) the evaluation of the "business guardian" prevails.

Bibliography
This unit of instruction is very specific to each alternator, so there is no bibliography.

Teacher
The Team is made up of tutors. They assist with support and assist alternates in case of problems.

Distribution of hours
Total: 4
Other: 4

Language(s) used during the course: French

Elective modules

Menu 1 - Object Schedule

Prerequisites: No

Learning Objectives
To know how to programme in an object-orientated approach, thanks to the C++ language. It is important to understand first that you do not approach a programme in the same way in both classical and object. Then, you have to have a global view of its decomposition into objects and use the concepts of this type of programming. A student who has taken this course must be able to structure and programme in C++, but also to quickly learn any other object language. This type of language is now essential for joining a business: it can be found at different levels and for very different programming, whether scientific, management, web or otherwise.

Description of the programme
Bases: C language on which C++.
C++ is written: the concept of reference; function parameter references, constant data references, default method arguments, overload of functions and methods, online functions, dynamic memory allocation, tables, variable declaration position, required prototyping, input/output, classes and objects, object arrays, attributes and methods and their accessibility, constructors and destructors, this pseudo-variable, static members, inheritance, super pseudo-variable, chained lists, operator overload, templates, notion of exceptions.

Target generic centrale-specific field-related skills and knowledge
This teaching unit provides the Central Engineer with unmissable computer bases, thus providing scientific and technical bases that are important for Scientific and Technical Innovation (Theme 1). Only with structured decomposition of problems can our engineers address complex systems (Theme 2): the object-orientated approach allows it.

Knowledge Control Procedures
For 20% of the score, a small job to do (CC) following a Practical Work, and for the remaining 80% a final project to do in tandem

Bibliography
Transparents
Henri Garetta, The C++ Language

Teacher
- C. Jazzar

Distribution of hours
Total: 30
Magistrates: 4
Directed work: 8
Practical work: 18

Language(s) used during the course: French

Elective modules

Menu 2 - Artificial Intelligence and Games

Prerequisites:

Common Trunk CoursePython
Programming

Learning Objectives

- Understanding the general principles of Artificial Intelligence algorithms for problem solving- Understanding the general principles of Artificial Intelligence algorithms for problem solving with opponents
-Being able to implement and adapt these general artificial intelligence algorithms to various use cases
- Understanding how machine learning can be used to improve fundamental algorithms

Description of the programme

Artificial Intelligence celebrates its 60th anniversary. It covers a range of issues and techniques that aim to carry out programmes for tasks that require intelligence when performed by human beings. While modern A.I. is essentially based on Machine Learning, older techniques allow attacking complex tasks such as problem solving, two-player games and more generally strategy games, and today benefit from advances in Machine Learning.

This elective introduces the techniques and tools of Artificial Intelligence necessary to realise artificial players for games with two players (Chess, Go, Backgammon...) and more generally for multiplayer games in general (Pacman) or strategy games. The course begins with:
- A brief introduction to the A.I.: The field of A.I., its history and a state of play today
- Troubleshooting by exploring, or how to write programmes that solve problems (problem of the eight queens, etc.) by effectively exploring sequences of actions
- 2-player games, or how to write a programme that plays against a human in games with limited number of actions, such as chess, ladies with alpha-type algorithms beta and its variants
- 2-player games and machine learning, or how to improve an artificial player with machine learning- Markov Decision Process and reinforcement algorithms: a special learning strategy adapted to the design of autonomous robotic agents, which can also be used for games with a large number of actions such as Go.

The module is taught for half in class sessions and for half in machine sessions (in Python).

Target generic centrale-specific field-related skills and knowledge

This module helps to give a broad view of the scientific and technological issues in the field of digital and artificial intelligence.
It trains the engineer to model sequential decision problems so that they can be solved with adapted tools of Artificial Intelligence:

- Scientific and technical innovation
- Control of system complexity

Knowledge Control Procedures

1 Project Rendering by Party (Troubleshooting, 2-Player Games, 2-Player Games and Machine Learning)
1 Final Review

Bibliography

Artificial Intelligence: A Modern Approach, 4th US ed. by Stuart Russell and Peter Norvig: http://aima.cs.berkeley.edu/

Teacher

- Thierry Artières

Distribution of hours

Total: 40
Magistrates: 14
Directed work: 16
Practical work:
Applied Jobs: 10

Language(s) used during the course: French

Elective modules

Menu 1 - Experimental and/or digital projects in the field of photonics

Prerequisites: No

Learning Objectives

This EU proposes to put into practice theoretical concepts and concepts seen in course, through experiments and numerical simulations that will be carried out in small groups of students, supervised by a teacher.
At the end of the course, students will know the technical details of the implementation (in laboratory or on computer) of two different subjects in photonics. They will also learn how these implementations can be used for practical applications.

Description of the programme

This year, 4 subjects will be proposed:

1. Laser cutting process: simulations and experiments. (L. Gallais)A
project combining numerical simulation of laser/material interaction and experiments to compare experiments/simulations to be carried out on the laser cutter installed in the practical workroom.

2. Digital simulations and experiments on the focusing of polarised beams. (N. Sandeau)A
project consisting of simulations and experiments on the numerically high-aperture focusing of a polarised laser beam in different media.

3. Interferential multilayer stacks. (F. Lemarquis)
Interferential multi-layer stacks enable many light spectral filtering functions such as anti-glare, mirrors, band-pass filters, high pass, low pass, and polarizers. After briefly presenting the whole topic (design, manufacture, and use), and presenting in detail the theoretical elements specific to these components, the teaching will consist of a project work that can cover various aspects of this theme, such as:
- the design of stacks (step of defining stacking formulas giving such or such filtering properties) through the use of dedicated software;
- the development of programmes of multilayer stacking calculations;
- activities between experimentation and numerical calculation such as the characterisation of thin-layer material index.

4. Optical consistency. (Mr. Alonso)
Brief presentation of the statistical theory of light in the description of coherence (spatial and temporal) and partial polarisation, followed by a numerical project to simulate these phenomena and some of their applications.

Knowledge Control Procedures
The methods of knowledge control will be in the form of two team projects.

Bibliography
Selected scientific articles

Teacher
- Miguel ALONSO
- Frédéric LEMARQUIS
- Laurent GALLAIS
- Nicolas SANDEAU

Sustainable development objectives (SDO)
3-Access to Health
4-Access to quality education
13-Combating climate change

Distribution of hours
Total: 30
Practical work: 30

Language(s) used during the course: French

Elective modules

Menu 2 - Energy & Environment

Prerequisites: No

Learning Objectives

The main objective is to know and understand the operation of modern thermal power plants.
This includes:
- A general approach on energy needs and in particular electricity
- Knowledge of thermodynamic production cycles and their optimisation
- Knowledge of the mechanisms of gas
combustion- An approach to sustainable water management (resources, analysis, control)
- Management of combustion gases by absorption

Description of the programme

- Evolution of needs and resources
- Environmental impact

- Basic information on fuels
- Problems of energy generation

- Water management and treatment

- Water resources upstream treatments combustion and pollutants
- Homogeneous combustion

- Combustion with/without premixtureAbsorption⇒- Different pollutants▪The main treatment processes▪Isootherm absorptionA visit to the Martigues thermal power station will be organised.

Target generic centrale-spécific field-related skills and knowledge

- Ability to take a global view and understand the problem in its complexity
- Ability to model and organise the resolution
- Ability to develop and understand a scientific and technical project

Knowledge Control Procedures

Assessment by Project: 100%
A thermal power plant sizing project will be passed on to students by binomial to implement all the knowledge and skills acquired during this module.

Bibliography

Woodruff, EB., Lammers, HB., Lammers, TF., *Steam Plant Operation*, 10th Edition. McGraw Hill Professional 2016.
Dincer, I., Zamfirescu, C., *Advanced power generation systems*, Amsterdam: Elsevier 2014.

Teacher

- Pascal Denis
-Pierrette Guichardon
-Pierre Boivin

Sustainable development objectives (SDO)

6-Access to safe water and sanitation
7-Use of renewable energy
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 30
Magistrates: 16
Directed work: 12
Other 2

Language(s) used during the course: French

Elective modules

Menu 3 - Economic philosophy

Prerequisites: No

Learning Objectives

- Understand the role of nature-culture dualism in the history of Western thought - Be able to articulate certain philosophical and economic issues related to the interdependence between the action of human beings and the functioning of the Earth system - Be able to explain the presuppositions of the arguments mobilised by the different protagonists in a controversy that puts economic and environmental issues into tension - Be able to mobilise a coherent normative framework in the formulation of an ethical assessment

Description of the programme

From a philosophical point of view, the anthropocene invites us to re-examine the natural/cultural dualism that has exercised a long hegemony over Western thought. From an economic perspective, the anthropocene raises new epistemological and ethical questions about growth and its colour (green or not green), indicators of wealth and well-being, "natural resources", the respective missions of the private and public sectors, and the role of businesses and citizens. At the crossroads of philosophy and economics, in this place where ideas common to the two disciplines emerge and flourish, some of the "ideas of the anthropocene", such as those of sustainable development, catastrophe, transition, metamorphosis, impact, but also the ideas that the anthropocene leads to revisit, such as those of planning, responsibility, freedom, equality or democracy I- Introduction /

II- The Idea of Anthropocene / III- Nature-Culture Dualism / IV- The Quest for Abundance / V- Uncertainty and the Figures of Change / VI- Democracy versus Authoritarianism: the question of freedom / VII- The end of the world or the end of the month: equality

Target generic centrale-specific field-related skills and knowledge

- C2: Complexity - The themes addressed by this elective allow to link the historical, social, political, philosophical and economic dimensions of contemporary problems. It contributes to the development of an understanding of the interdependence of the "natural" and "cultural" dimensions of phenomena.
- C4: Ethical and Responsible Management - Education aims to deepen the understanding of certain ethical controversies that arise in the pursuit of the common good and to better understand the representations underlying different points of view.
-C5: Vision and Strategy - This elective contributes to a better understanding of certain contradictions at work in the evolution of the contemporary world.

Knowledge Control Procedures

A written record of approximately eight pages on a theme chosen by the student in consultation with the teacher. (100% written)

Bibliography

Bonneuil, C., Fressoz, J. (2016), *The Anthropocene Event. The Earth, History and Us* (History Points). POINTS.
Charbonnier, P. (2020), *Abundance and freedom*. La Découverte.
Latour, B., (2015), *Face à Gaïa - eight lectures on the new climate regime*. Discovery.

Teacher

- Guillaume Quiquerez

Sustainable development objectives (SDO)

1-Eradication of poverty
10-Reducing Inequality
12-Responsible consumption and production
13-Combating climate change
17-Partnerships for the achievement of objectives

Distribution of hours

Total: 30
Magistrates: 6
Directed work: 10
Practical work: 3
Applied Jobs: 13

Language(s) used during the course: French

Elective modules

Menu 2 - General Culture

Prerequisites: No

Learning Objectives

This course works on major contemporary issues in the light of major works and works (Philosophy, Sociology, Arts, Literature).
It allows the following:
- To grasp the current major debates (on ecology, transhumanism, antispecism...) while building a solid culture (knowledge of major writings, essential authors, etc.).
- To develop the capacity to question and argue.

Description of the programme

The course will be structured around the following themes:
- Master and possessor...
- Man and nature
- Antispecism
- Transhumanism

Target generic centrale-specific field-related skills and knowledge

- C2: Complexity
The themes addressed by this election make it possible to link the social, political, economic, legal and cultural dimensions of contemporary phenomena. It helps develop critical thinking and the ability to argue.

-C5: Vision and Strategy
This elective contributes to a better knowledge of the evolution of the contemporary world and the major challenges that are its way through it.

Knowledge Control Procedures

The evaluation will be conducted in the form of a 2-hour review of the knowledge acquired during the course.

Bibliography

Cf. moodle

Teacher

- Lucie Luthereau

Sustainable development objectives (SDO)

5-Gender equality
10-Reducing Inequality
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 30
Magistrates: 20
Directed work: 10

Language(s) used during the course: French

Elective modules

Menu 1 - Law and Sociology of Organisations

Prerequisites: Have experience in an organisation (internship in a company, associative engagement...)
EU SHS

Learning Objectives

- To know the analytical keys of the sociology of organisations to understand and analyse the concrete problems posed by the life of organisations, understood as systems of interdependent actors: How do we ensure coordination and cooperation between individuals? How does individual motivation work? What incentives are there to encourage people to get involved? How do we understand power relationships, regulate conflicts, and foster cooperation?
-Mobilise the methodologies and concepts of the sociology of organisations to carry out the diagnosis of a lived organisational situation or decision-making process
- Understand the legal issues associated with the life of organisations, especially in the context of companies and associations
- Know the normative sources and their articulation (social law, contract law)
- Understand the context and ways of solving legal conflicts

Programme Description

SOCIOLOGY
1. Organisational
Structures and Arrangements 1.1. The Rationalisation of Organisations
1.2. Organisational
Configurations 2. Psychosociological Approaches of Organisations
2.1. The "Human Factor", Limit of Rationalisation
2.2. Theories of Motivation
3. Strategic Analysis of Organisations
3.1. Methodology and Concepts of Strategic Analysis (power)
3.2. Cooperation and conflict in organizations LAW

1. Legal organisation: structure and foundations
1.1. Rule of law
1.2. Sources of law
1.3. The legal organisation and hierarchy of norms
1.4. Fundamental principles: Evidence, Reconciliation and Accountability
2. The individual in the organisation: social
law 2.1. Individual aspects of labour
law 2.2. Collective aspects of labour
law 3. Contract: an area of freedom, will and individual
negotiation 3.1. The formation of the contract
3.2.

Target generic centrale-specific field-related skills and knowledge

- C2: Understanding organisations as systems of interdependent actors. Identify and explain the mechanisms for regulating behaviour in an organisation through a systemic approach.
- C4: Formulate recommendations to support change based on a rigourous and structured diagnosis of individual and collective opportunities and barriers. Integrate individual and collective social and legal considerations into its analysis and recommendations. Develop cooperation and participation. Design and develop a management that supports global and sustainable performance.

Knowledge Control Procedures

100% continuous control with:
- 60% Sociology (individual file)
- 40% Right (exam)

Bibliography

Alexandre-Bailly, F. (dir.), *Human Behaviour and Management*, Pearson, 4th edition.
General Introduction to Law, Dalloz.

Teacher

- Laetitia PIET (resp.)
- Isabelle VASSEROT

Distribution of hours

Total: 30
Magistrates: 18
Directed work: 10
Applied Jobs: 2

Language(s) used during the course: French

Common Trunk

Social Sciences

Prerequisites: No

Learning Objectives

Acquire the analytical keys for HSS:
- Learn about the reasoning and conceptualisation of HSS, mainly sociology and psychology
- Analyse complex social and organisational systems by mobilising HSS concepts and theories, and articulating macro and micro (society, organisation, group, individual)
- Read and interpret statistical data on societal issues (especially on working conditions, employment) and their evolution)
- Understanding the dilemmas of management of men and organisations

Integrating HHS into professional practice:
- Implement a rigourous approach that distinguishes the stages of description, analysis and advocacy, in the face of social, organisational and human issues
- Formulate hypotheses to explain and understand human behaviours in their context

Description of the programme

1. Introduction to the Humanities and Social
Sciences - Presentation of the approach of reasoning and conceptualisation specific to these scientific fields
-Introduction of the fundamental concepts of sociology and psychology, to understand human behaviours, social structures and their dynamics (socialisation, social integration, identity, social influence, social representations, perception bias)

2. Individual, work and organisation
- Issues related to work, collective dynamics and individuals in the company, from the foundations of management to the contemporary
period - Focus on the transformations of the roles and professional identities of executives and engineers.
- Study of organisational innovations such as the liberated enterprise: management roles, behavioural regulation (autonomy/control)
- Focus on mental health at work and quality of life issues at work

Target generic centrale-specific field-related skills and knowledge

- C2: Develop a systemic approach to human organisations and articulate micro and macro levels in the analysis of these systems.
- C4: Design management modalities that integrate health and quality of life issues at work.
Formulate recommendations to accompany organisational changes that promote social dialogue, skills development, health at work.
Facilitate and regulate a working team: organise, position itself in a group, regulate conflict, communicate.
Become aware of its modes of operation, its sources of motivation, its preferential roles, its

biases.
- C5: Analyse the relationships between strategy and corporate culture and understand the operational variations that result.

Knowledge Control Procedures
100% continuous control regular work to be carried out in teams of 5 students

Bibliography
See moodle as sessions go on.

Teacher
- Laetitia PIET (Head of EU)
-Florian MAGNANI
- Maxime BELLEGO
-Yohann DESBOIS
-Nicolas BELTOU

Sustainable development objectives (SDO)
5-Gender equality
10-Reducing Inequality

Distribution of hours
Total: 48
Magistrates: 24
Directed work: 8
Practical work: 4
Applied Jobs: 12

Language(s) used during the course: French

Common Trunk

Deepening Chemistry - Process Engineering

Prerequisites: No

Learning Objectives

Chemistry:
- Knowledge of the principles of kinetic or thermodynamic control, load control, orbital or steric underlying chemical
reactions - Knowledge of the properties and reactivity of benzene and its derivatives.
Knowledge of the properties and responsiveness of carbonyl function, a highly versatile chemical function of organic
chemistry - Knowledge of the electronic structure of organometallic complexes, the nature of metal-ligand binding and ligand substitution mechanisms - Oxidising addition - Reductive elimination - Insertions and eliminations process engineering:
- Knowledge of material transfer for a continuous medium and in the vicinity of an interface
- Apply this knowledge to liquid-liquid extraction without partial miscibility to the size of a mixer-settler battery, a tray column and a filling column

Description of the programme

CHEMISTRY:
Organic and organometallic reactivity:
- 1st part: Electrophile addition to alkene - benzene and its derivatives: aromaticity, resonance - benzene reactivity and its derivatives: aromatic electrophilic addition (halogenation, nitration, sulfonation - alkylation of Friedel and Crafts) - polysubstitution: regioselectivity
- 2nd part: structure and properties of carbonyl function - preparation of carbonyl derivatives: oxidation of alcohols, transposition - reactivity of carbonyl derivatives: nucleophilic attack by water, alcohols, amines, reduction by hydrures and organomagnesians and organolithians, ylures (Wittig reaction) - oxidation of ketones, enols and enolates: C-alkylation and O-alkylation, aldolisation
- 3rd part: organometallic chemistry and catalysis, organometallic complexes: electronic structure of complexes - metal-ligand binding - reactionary mechanisms - ligand substitution - oxidant addition - reducing elimination - insertions and eliminations - reactions on the coordinated ligands - general principles of catalysis: hydrogenation -

hydroformylationPROCESS ENGINEERING**:Material**
Transfer:
- Continuous transfer of material, mechanisms: diffusion and convectionLocal balance: continuity
equation - transferring material to an interface: model of film, transfer coefficients, dimensional analysis and major additional numbers, analogy

Liquid-liquid extraction:
- Introduction to separative
methods- The theoretical
stage- The battery of cross
-current mixers-decanters- The tray
column- The filling column

Target generic centrale-specific field-related skills and knowledge

Chemistry
- Understanding the chemical reaction in terms of kinetic or thermodynamic control, load control, orbital or steric to predict and control the selectivity and stereochemistry of the formed
products - Being able to predict the reactivity of an organometallic complex according to the nature of the metal and its ligands, predict its structural and electronic changes throughout a catalytic cycle in contact with the reaction medium

Knowledge Control Procedures

DS Chemistry (2/3) - GP (1/3): 50%
CC (Directed + Practical + Applied) Chemistry (2/3) - (Directed + Applied) GP (1/3): 50%

Bibliography

Online resources on the educational portal of the
Central SchoolWorks (documentation centre)

Teacher

Chemistry :
- Bastien Chatelet
- Didier Nuel
- Laurent Giordano
- Alexandre Martinez
- Innocenzo De Riggi
- Anne-Doriane Manick
- Cédric Colomban
- Louise Miton
- Émile Vandeputte

Genie des Procédés :
- Pierrette Guichardon
- Pascal Denis- Nelson Ibaseta
- René Arnaud

Sustainable development objectives (SDO)

12-Responsible consumption and production

Distribution of hours

Total: 72
Magistrates: 24
Directed work: 22
Practical work: 8
Applied Jobs: 18

Course languages: French - English

Elective modules

Menu 3 - Remote sensing and applications

Prerequisites: No

Learning Objectives
The aim of this course is to present the methodology specific to the field of remote sensing and to present various applications.
An important part of the teaching is carried out around practical work so that students can face the difficulties of analysing experimental data. External stakeholders from large organisations and companies in the sector are organised to promote openness to modern applications and trades.

Description of the programme
The application context of this course is remote sensing in the sense of environmental perception. The programme consists of presenting the general problem and then presenting the specific methodology. For this teaching, the courses and practical work sessions are held so that students can face the difficulties and develop their data analysis skills. Seminars with external stakeholders from large organisations and companies in the sector are organised to promote openness to applications and professions. Concrete applications are discussed.

Target generic centrale-specific field-related skills and knowledge
The competencies are:

- Developing critical
thinking - The ability to synthesise the results of an experiment (especially the ability to take account of randomness) and the ability to formalise a problem with a view to solving it

Knowledge Control Procedures
1 CC a robust average of Practical Work reports:

Bibliography
The Knight, Principles and Treatment of Radar and Sonar Signals, Masson.

Teacher
- A. Roueff
- R. Marion

Distribution of hours
Total: 30
Magistrates: 14
Practical work: 16

Language(s) used during the course: French

Elective modules

Menu 1 - Macroeconomics and Economic Policy

Prerequisites: No

Learning Objectives
This course provides an overview of macroeconomics by explaining the concepts of discipline in a simple and rigourous manner: What does GDP measure? Why are we looking for growth? What are the effects of inflation? How does unemployment appear? What is an exchange rate? What are financial markets for? We will approach this using the major macroeconomic models, both closed and open. Special attention will be paid to the analysis of economic policies and their impacts on the various key economic variables.

Description of the programme
In this course we will focus on short- and medium-term macroeconomics. Special attention will be paid to the analysis of economic policies and their impacts on the various key economic variables. This analysis will be conducted throughout the course using modelling. The plan (forecast) is as follows:
- Chapter 1: Key Economic Indicators

- Chapter 2: The classic model

-Chapter 3: Currency and Inflation
- Chapter 4: Unemployment

- Chapter 5: Short-term macroeconomics

- Chapter 6: Medium-term macroeconomics: price recognition

-Chapter 7: Macroeconomics in an open world. Students wishing to study long-term macroeconomic analysis may wish to move towards the EU of Economics of the DMC course.

Target generic centrale-specific field-related skills and knowledge
- C2: Control of the complexity of economic systems in which economic agents operate.
- C5: This course also provides a strategic vision by understanding the implications of government-led economic policy choices.

Knowledge Control Procedures
100% table exam

Bibliography
Gregory N., Mankiw *Macroeconomics*, De Boeck.
Olivier Blanchard and Daniel Cohen, *Macroeconomics*, Pearson.

Teacher
- Nicolas Clootens

Sustainable development objectives (SDO)
1-Eradication of poverty
8-Access to decent jobs
10-Reducing Inequality

Distribution of hours
Total: 24
Magistrates: 16
Directed work: 8

Language(s) used during the course: French

Common Trunk

International Languages and Cultures

Prerequisites: No

Learning Objectives

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

The Engineer · Central · Marseille will have to be able to interact accurately and effectively with partners of 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:

LCI education comprises two separate lessons per semester: English (LV1) 8 pm and another language (LV2) 8 pm.

Attention: students enrolled · e · s in Double Degree will follow 2 FLE lessons (LV1 and LV2) at S5 and S6.

These 40 hours of face-to-face courses are completed by 10 hours of personal work (autonomous work, research, exercises...) per language and per semester.

LCI is taught at a rate of 2 hours per language per week. Groups of levels are formed following evaluation tests in English, French, Foreign Language, German and Spanish.

For beginner level LV2 students will be given 10 hours (Italian, Spanish, Portuguese) or 15 hours (German, Chinese, Japanese, Russian) of additional support courses.

N. B.: Students will not be able to start a language in semester 7.

Generic Central Skills and Knowledge in the discipline:

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: the IC 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 ·.

Bibliography

According to the courses chosen.

Teacher

- English: P. Atkinson, J. Airey, V. Durbec (Head of EU), G. Marquis, M. McKimmie
-Espagnol: 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
-Arabe: B. Zoubir
- Russian: Y. Yurchenko
-Portuguese: S. Almeida

Sustainable development objectives (SDO)

5-Gender equality 7-Recourse to renewable energies 10-Reducing inequalities 12-Responsible consumption and production 16-Justice and peace

Distribution of hours

Total: 40
Directed work: 40
Applied Jobs: 20

Language(s) used during the course: English

Elective modules

Menu 1 - Applied Mechanics - Flight Structures, Aerodynamics and Mechanics

Prerequisites:

Mechanics of continuous environments, linear elasticity, fluid mechanics

Learning Objectives

- To acquire the knowledge necessary to understand the structure models (hypotheses and application framework), as well as the related sizing methods:
- To model the beam
-based structures- To master the sizing methods in linear
elasticity- To know to pose and analyse a problem of sizing the beam lattices in a software finite
elements- To acquire the basic concepts in aerodynamics:
- Knowledge of the basics of aerodynamics around profiled
obstacles - Knowledge of how to size the forces on bearing
profiles - Understanding the concept of local models in fluid
mechanics - Learn the fundamental notions in meteorology and flight mechanics:
- Understanding the structure of the atmosphere, as well as the genesis of the weather
disturbances - Know how to calculate wind from pressure maps▪Understanding aeroplane aerodynamic operation in flight

Description of the programme

1ST PART: STRUCTURES
- Three-dimensional elastodynamic reminders (kinematics, aesthetics, Hooke's law, local equations, integral formulations)
- Beams models:
- Saint Venant
principle- Cinematic hypotheses of Euler-Navier-Bernoulli
- Establishment of the thin
beam model- Energy theorems (Ménabréa and Castigliano)
- Dimensioning

2TH PART: AERODYNAMICS
- Incompressible
Fluid Mechanical Reminders- Potential
Flow- Aerodynamic
Factors- Laminar/Turbular Limit Layer

3RD PART: FLIGHT
MECHANICS- Initiation to Meteorology:
- Air Structure and Numerical Values of the Atmosphere
- Geostrophic and Local
Wind- Clouds
- Fronts and Disturbances

- Flight Mechanics:
- Aerodynamics of a bearing
profile- Marginal
vortices- High lift

flaps- Controls - Straight horizontal flight⇒- Climb and descent: slope and climb
speed - Flight stability

Target generic centrale-specific field-related skills and knowledge

- C1: Master modelling tools to validate innovative technological solutions
- C2: Ability to model and analyse complex structures
- C2: Master sizing methods
- C2: Ability to calculate aerodynamic forces on structures
- C2: Understanding the basics of meteorology
- C2: Understanding the Complexity of Aircraft Flight

Knowledge Control Procedures

DS (2h written exam): 65%
CC (3 HW CR): 35%

Bibliography

Ballard, P. and Millard, A., *Elastic beams and bows*, Ed. École Polytechnique, 2009.
Paraschivoiu, I., *Subsonic aerodynamics*, Ed. École Polytechnique de Montréal, 2003.
Kundu, P.K., and Cohen, IM, *Fluid mechanics*, Elsevier, 2010.
Malardel, S., *Weather Foundations*, Cépaduès - Météo France, 2008.
Bonnet, S., Glass, J., *Flight Mechanics for Light Aircraft*, Cépaduès, 2006.

Teacher

- Stéphane Bourgeois
- Olivier Boiron
- Olivier Kimmoun

Sustainable development objectives (SDO)

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

Distribution of hours

Total: 30
Magistrates: 14
Directed work: 8
Practical work: 8

Language(s) used during the course: French

Elective modules

Menu 3 - Hyperfrequencies and Radio Frequencies

Prerequisite:

Electromagnetism, Electricity, Quantum Physics

Learning objectives

After having assimilated some theoretical bases to the foundation of fast electronics, this option helps to understand the hardware operation of a large number of very current applications in the fields:

- ・ Signal (ADSL, mobile telephony, WiFi, electronic labels = RFID, electronic toll, radio and TV)
- ・ Measuring (radar, magnetic resonance)
- ・ Energy (microwave, drying, safety standards)
- ・ Quantum physics

Description of the programme

The teaching of this vast field will focus on 3 orientations:
- Microwave circuits (J. Bittebierre)
- Antennas (F. Lemarchand)
- Emerging application of Quantum Physics in microwave (T. Durt)

List of applications of microwave and radio frequencies:
- Signal: computer clock frequency, aerial transmissions (mobile, satellite, WiFi, Bluetooth, TNT, cable transmissions: ADSL)
- Power: microwave heating, drying, vulcanisation, sintering; generation of Plasmas: for ITER for the semiconductor industry; armaments
- Metrology: geographical: radar, radio astronomy, GPS; spectroscopic: RPE, NMR. EM compatibility (emission and effects of EM parasites by and on circuits)
- New quantum applications (= where photons are treated individually or in very small groups and not in very large numbers randomly by Maxwell): quantum radar, quantum sources, quantum information

Target generic centrale-specific field-related skills and knowledge

- EU is approached simultaneously by the circuit aspect and the aspect of electromagnetic waves (at these frequencies there is a surface current in the conductors, and electromagnetic waves in their environment). The introduced electromagnetic concepts may be used in other options (e.g.: fibre optics).
- Hyperfrequency heating is a multidisciplinary application (propagation of EM waves, thermal waves, microscopic physics).
- The discussion of authorised frequencies and safety standards allows to exert critical meaning on regulatory aspects and societal issues.
- Quantum applications are examples of the use of basic knowledge seen in quantum physics.

Knowledge Control Procedures
Continuous control to be defined

Bibliography
Engineering techniques in the field

Teacher
- Responsible: Jean Bittebierre
-Teaching Team: Jean Bittebierre, Thomas Durt, Fabien Lemarchand

Sustainable development objectives (SDO)
3-Access to Health

Distribution of hours
Total: 30
Magistrates: 28
Practical work: 2

Language(s) used during the course: French

Elective modules

Menu 2 - Material Radiation Interaction

Prerequisites:

Quantum physics, bases of electromagnetism

Learning Objectives

Understand the basic concepts and theory of the main physical phenomena interacting electrons and photon radiation in matter. Illustrate them in particular by the operation of lasers and their use to modify the material under high energy laser pulses. Observe these phenomena in living matter that allow the transition from molecular imaging to medical diagnosis. Expand in case of radiation and various particles (neutrons, X-rays...). Be able to give a presentation on a topic of choice in the field.

Description of the programme

1. Lasers: Understanding the laser (The photon and the electron; absorption, stimulated and spontaneous emissions; optical pumping; black body). Illustration by laser materials related to atomic physics, and use of lasers in the rest of the course.

2. Laser interaction material: Introduction to the different categories of physical phenomena involved (photothermal, photo-ionisation, photomechanical...). Illustration by applications in industrial fields (additive or subtractive manufacturing, thermal treatments), or medical (skin treatments, ophthalmic surgery). Practical Work: digital software made using Comsol, multi-physical software (e.g. laser welding).

3. Introduction to biophotonics: Applications of light-matter interactions to the study of complex systems: from cells to tissues. Study of fluorescence imageries and coherent imageries to understand life or make early diagnosis.

4. Atomic Physics: Study of the interaction between electrons and photons in polyelectronic atoms due to physical phenomena much finer than those seen in quantum physics. Probabilities of transitions between energy levels. Zeeman and Stark effect of external static fields. Illustration on rare earth ions used in laser amplifiers and optical fibre telecommunications, atomic clocks, magnetic resonance...

5. Notions on the interaction of matter with various particles: X-ray diffraction and neutrons in relation to large installations in Grenoble (ESRF and ILL)
- http://www.esrf.eu/
- http://www.giant-grenoble.org/fr/institut-laue-langevin-ill/

6. Hearing of other students' presentations: Application topics validated by teachers and extending the course.

Target generic centrale-specific field-related skills and knowledge

EU giving the keys to really understand the material-radiation interaction (often used but only discussed in other EU applications), allowing students to imagine and innovate beyond being mere users:
- Enables the mobilisation of an interdisciplinary culture between quantum, microscopic and macroscopic matter and radiation.
- Understanding the course of understanding and formulating complex problems by analysing the different orders of magnitude of the phenomena concerned.
- Exercises the ability to rapidly deepen a field while understanding all its scientific and technical dimensions.
- Exposure of deepening practising to produce a bibliographic research, stimulating imagination.

Knowledge Control Procedures

Continuous control to be specified among courses, lectures, homework, report of Practical works: (ongoing reform)

Bibliography

Claude Cohen Tanoudji and Coll, *Quantum Mechanics*, Hermann, 1977.
Christian Delsart, *Lasers and non-linear optics*, Ellipses 2008, ISBN978-2-7298-3856-0 Centre Doc ECours: 626.1.
BEA Saleh, MC Teich Wiley, *Fundamental of Photonics*, 1991, ISBN 0-471-83965-5 Centre Doc ECours Magistraux.
B. Cagnac, JC. Pebay-Peyroula, *Atomic Physics*, Dunod University 1975.

Teacher

- Responsible: Jean Bittebierre
- Teacher: Jean Bittebierre, Laurent Gallais, Nicolas Sandeau
- External speaker of ESRF: Yves Joly

Sustainable development objectives (SDO)

3-Access to Health

Distribution of hours

Total: 30
Magistrates: 22
Directed work: 4
Practical work: 4

Language(s) used during the course: French

Elective modules

Menu 2 - Challenges of Modern Chemistry

Prerequisites:
Organic chemistry bases

Learning Objectives
The growing interest in a more responsible chemical industry leads to the development of a chemistry commonly called "green chemistry".
In this teaching, we will focus on the 9th principle of green chemistry: catalysis and, in particular, homogeneous catalysis. This theme will be addressed through an original approach to the chemical reaction. It will be necessary to understand how a catalysed reaction works in order to optimise it effectively in a spirit of sustainable development.
The learning objectives can be as follows:
- Understanding the functioning of a catalyst and its corollary, the catalysed reaction- Understanding the key parameters of a catalysed reaction- SSS have optimised parameters
- Implement a catalysed reaction - Report

Description of the programme
This option begins with an introduction to organometallic chemistry (transition element chemistry). This preamble aims to understand the basic steps of a catalytic reaction, preliminary to an optimisation of parameters.
The catalytic oxidation reactions and their pendants, the reduction reactions will then be developed.
The sessions of Directed Work: will be devoted to the study of publications on very recent aspects of these two types of reactions.
Finally, a series of Practical works in which participants will have to synthesise a catalyst before implementing it in an adapted reaction.

Target generic centrale-specific field-related skills and knowledge
This elective can perfectly fit into the mastery of complex systems, because mastering the many parameters that govern the functioning of a catalysed reaction in order to optimise its functioning requires the use of knowledge from various fields of chemistry.

Knowledge Control Procedures
- A report on a study of a recent original synthesis - Practical reports

Bibliography
Astruc, D. (2013), *Organic Chemistry and Catalysis*, EDP SCIENCES.
Behr, A., Vorholt, A. J. (2017), *Homogeneous Catalysis with Renewables*, Springer.

Sheldon, R. A., Arends, I. Hanends Fefeld, U. (2007), *Green Chemistry and Catalysis* (1st ed.), Wiley-VCH.

Teaching team:

- Laurent Giordano
- Didier Nuel

Sustainable development objectives (SDO)

12-Responsible consumption and production

Distribution of hours

Total: 30
Magistrates: 6
Directed work: 12
Practical work: 12

Language(s) used during the course: French

Elective modules

Menu 3 - RIS

Prerequisites: No

Learning Objectives

The separation of the components of a mixture, their identification and their quantification are daily problems for synthetic chemists, both in the laboratory and in the industry.
This option aims to address the different aspects of this problem in the form of mini-projects in which a small team will determine a method of separation of the components of a mixture, then characterise them and, of course, quantify them.
In terms of objectives, it is Participants expected the following learning:
- Building a Scientific
Approach- Defining an Experimental
Protocol- Implementing an Experimental
Protocol- Using Methods for Identifying Chemical
Compounds- Using Methods for Quantifying the Components of a Chemical
Mixture- Having a Critical View on the Results Achieved
- Drafting a Report
- Presenting Results orally

Programme Description

The majority of slots will be dedicated to practise to the chemistry platform. The best method of separating the components of a mixture (known in advance) will be determined and applied. Then, methods of identifying the different components of the mixture will have to be quantified and proposed.
Among the mixtures proposed in previous years, there will be dyes, active ingredients of medicines or components of foodstuffs (chocolate or tea, for example).
There will also be some presentations of modern techniques Identification and quantification of compounds (NMR., HPLC, IR Spectroscopies and UV-Visible...).

Target generic centrale-specific field-related skills and knowledge

This is part of the complex environments,
it is about properly modelling the system to determine and implement the best solution.
As the work is carried out within a small team, it will also be necessary to organise the work of the group to carry out the project.

Knowledge Control Procedures

- Written
report - Oral presentation

Bibliography

Rouessac, F., Rouessac, A. (2009), *Chemical Analysis* (7*th* ed.), Dunod.
Skoog, D. A., West, D. M. (2015), *Analytical Chemistry* (2015) (French Edition) (3 De Boeck Sup.
Gilbert, M. T. (1987), *High Performance Liquid Chromatography, John Wright.*
Snyder, L. R., Kirkland, J. J., Dolan, J. W. (2009), Introduction to Modern Liquid Chromatography (3rd ed.), Wiley.

Teacher

- Riggi
Innocenzo - Didier Nuel

Sustainable development objectives (SDO)

6-Access to safe water and sanitation
12-Responsible consumption and production

Distribution of hours

Total: 30
Magistrates: 2
Practical work: 28

Course languages: French - English

Common Trunk

Electronics Automatic Electrical Energy

Prerequisites:

Resolution of differential equations, Fourier series and transformation, Laplace transformation, Boole algebra, combinatorial logic, sampling theory.

Learning Objectives

The teaching of Tronc Commun E3A enables students to acquire and master methods of analysis and synthesis of electronic systems in a broad sense, enabling them to grasp complex and transdisciplinary problems.

In particular, the student will be able to:
- Master the concepts for drawing up a specification and summarise a montage using the appropriate tools.
- Understand, analyse and then design a filtering and amplification system for an actual analogue signal, source or sensor.
- Mastering the basic tools of the Automatic, being able to associate the temporal behaviour of a system with a model.
- Mastering the circuits specific to the digital electronics, and putting into practice the methods of synthesis of assemblies with sequential operation using memories, machines with finite states, and Arithmetic and Logic units.
- Knowing the architecture of a basic system and presenting elements of a simple microprocessor-based system.
- Evaluate the criteria for choosing an N/A and A/N conversion system according to the type of application concerned.
- Gain the basis for understanding the electrical energy conversion systems by mastering the various functions of these systems.

Description of the programme

Analogue Electronics
- Linear Systems and Signals
- Filtering, Representation
- Input/Output/Gain
Impediments- Quadripole Notion, Setting, and Associations
- Real Operational Amplifiers

Automatic Linear
Systems- Introduction to Automatic Positioning in the Engineering
Business- Modelling Systems: knowledge model, driving model for systems of higher order than two, identification
- Analysis of behaviour of closed
systems- Stability study: algebraic method, Evans site, frequency

method- Precision
- Synthesis of a command from a

specification Digital
electronics- Digital and embedded
electronics- Comparative characteristics of analogue and digital
signals- Design of circuits based on elements of combinatorial logic, sequential logic and state
machine- Memory and micrographs Processors
- A/N and N/

Electric

energy converters- Single phase and three phase electric circuits, balanced and unbalanced- Functioning and characteristic mechanisms of power electronics components in switching[1]- Computerised energy conversion systemsMicrocontrollers[1]- Basic system architecture⇒- Programming/instructionset[1]- Micro micro processors, microcontrollers and DSP

Target generic centrale-specific field-related skills and knowledge

- Ability for a student to identify the elements necessary for the understanding of complex electronic systems (analogue and/or digital) and then to understand all their scientific and technical
dimensions - Mastery of basic methods and tools for the analysis and synthesis of digital electronic systems
- Mastery of basic methods and tools for the analysis and synthesis of the command of linear slave systems
- Ability to understand basic principles and the purpose of power electronics and AC/DC converters
- Ability to understand all the scientific and technical dimensions of all the elements of an electric power conversion chain from a specification

Knowledge Control Procedures

The assessment of the E3A EU shall be carried out by continuous monitoring, in the form of duties monitored on the table and/or online and/or orally during the sessions of Applied or Directed Works. The number of ongoing checks is a maximum of 10. The Practical Work is also evaluated and involved in the final evaluation. The final score of the evaluation is a weighted average of the scores for the various evaluations.

Bibliography

Schubert, Kim, *Fundamentals of electronics*, Morgan & Claypool publishers, 2013.

Floyd, Buchla, Electronics Fundamentals Circuits, Devices, and Applications, 8th edition, 2014, Pearson.
Floyd, *Digital Fundamentals*, 11th edition, Pearson, 2015.
Larminat, *Command of Linear Systems*, Hermes Science publication, 1996.
Granjon, *Automatic 3th edition*, 2015, Dunod.

Teacher

- Læ titia Abel-Tiberini
- Nicolas BERTravals applied: UX,
-Mohamed Boussak
- Thierry Gaidon
- Guillaume Graton
- Alain Kilidjian
- Fabien Lemarchand
- Vacancies

Sustainable development objectives (SDO)

7-Use of renewable energy
11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours

Total: 99
Magistrates: 32
Directed work: 22
Applied Jobs: 18
Other: 27

Language(s) used during the course: French

Elective modules

Menu 3 - Continuous Media Dynamics

Prerequisite:

The 1st year continuous mechanical/mechanical courses are sufficient.

Learning Objectives

Continue/deepen the mechanical training of continuous environments with emphasis on dynamic movements and phenomena.

In particular:
- Know the basic concepts used by engineers in the field of dynamics, vibration and acoustics in fluids and solids. On the basis of a series of practical works and two basic courses reduced to essentials, a number of dynamic phenomena, of a vibratory or acoustic nature, which manifest in these environments are presented and modelled. It is shown how engineers use them for the design, optimisation, monitoring or maintenance of industrial mechanical systems.
- Knowledge of the essential bases and properties of turbulence, in order to be able to treat and model the various practical situations that will appear in S9 or during courses in international mobility. The theoretical basis for analysing and modelling the phenomena associated with turbulent flows will be laid. This helps to make students aware that, in nature and industry, flows are essentially turbulent. Treating these flows requires specific skills and tools (both analytical and modelling) that are very different from those used for laminar flows (seen in 1st year).

Description of the programme

For the part on dynamics, vibrations and acoustics, some examples of Practical works that complement the two courses:
- Experimental determination of a mode of vibration
- Reconstruction of a movement by modal
superposition- Measurement of the acoustic power of a source
- Measurement of the absorbent properties of materials
- Analysis of audio signals, levels and sound
indicators- Digital calculation of modes Structures with Abaqus and Matlab software (using the finite element method and the Ritz method)

For the part on turbulence initiation in fluid mechanics:
Four courses on:
- Turbulence appearance, laminar/turbulent transition, need for statistical treatment (decomposition of Reynolds)
- Balance equations for average sizes, Reynolds voltages, kinetic energy of turbulenceDjiboue

- Basic modelling (mixing length, turbulent viscosity), characteristic scales, Kolmogorov

- Application in case of mixing of a scalar, turbulent diffusivity, analogy with random walking (but with scales of length and velocity characteristic of the flow and not of the fluid as in laminar

regime) courses are supplemented by sessions of Directed Works: (4 Hour-directed work), to illustrate the concepts presented in the course with some concrete examples.

Target generic centrale-specific field-related skills and knowledge

- C1: Scientific and technical innovation: For example, to prepare for an S8 laboratory internship in one of these fields or for an international academic course in a speciality related to mechanics where these notions will be repeated much more thoroughly
- C2: Control of Complexity and Systems:
- Learn to model and analyse a problem, choosing the most relevant method and/or level of modelling (C2)
- Master the basics of numerical modelling/simulation methods associated with these types of situations, for example, doing the 2A course in one of the relevant fields (C2)
- Know how to interpret results of experience (C2

Knowledge Control Procedures

- Five Practical Work Tests noted (organisation in pairs or triples with a mandatory report at the end of each session): (50%)
- A written 2-hour turbulence test: (50%)

Bibliography

M. Abid, F. Anselmet and C. Kharif, *Hydrodynamic Instabilities and Turbulence*, Cépaduès Éditions (2017)

Teacher

- F. Anselmet
- S. Bourgeois
- B. Cochelin
- Mr. Jaeger
- C. Maury
- D. Mazzoni
- E. Sarrouy

Sustainable development objectives (SDO)

4-Access to quality education
7-Use of renewable energy
8-Access to decent jobs
12-Responsible consumption and production
13-Combating climate change

Distribution of hours

Total: 30
Magistrates: 12
Directed work: 8
Practical work: 10

Language(s) used during the course: French

Elective modules

Menu 3 - Web Development

Prerequisites: No

Learning Objectives
This election aims to discover the world of web creation, on the computer side. You will learn what a website is, a web server and how to create them.
After the introductory courses allowing you to understand the field, the EU will be entirely realised in project mode with regular progress points.
At the end of this course you will have good knowledge in web front (html, css, js).

Description of the programme
Almost entirely in project mode, this EU should allow you, according to your desires and your level, to introduce yourself to a particular development model. For example:
- the basis of the web with css, html and js files

- the use of a static site creator like jekyll
- the development of interactive documents with 3djs.This EU is not reserved for computer enthusiasts, even if you have to have nothing against writing a little code. Anyone interested in the subject will be able to develop their computer skills in general and in the web in particular. Once you have completed this EU, whether you are a beginner or an amateur developer, you will have understood what web development is all about and will be able to build your own websites by finding and understanding the right resources on the Net.

Target generic centrale-specific field-related skills and knowledge

Knowledge Control Procedures
Continuous

Bibliography

Teacher
- François Brucker

Sustainable development objectives (SDO)
8-Access to decent jobs

Distribution of hours
Total: 30

Language(s) used during the course: French

Elective modules

Menu 3 - Computer Theory

Prerequisites: No

Learning Objectives
Have an overview of the theoretical aspects of IT.

Description of the programme
- Language theory (regular languages, algebraic languages, deciding languages, recognisable languages)
- Turing machines, finished automata, battery-operated automata, linear terminal automata
- Calculability.
- Complexity theory (complexity in time, complexity in space, probabilistic complexity classes, complexity of Kolmogorov)

Target generic centrale-specific field-related skills and knowledge
Curiosity and reflection

Knowledge Control Procedures:
Terminal Review

Teacher
- Pascal Préa

Sustainable development objectives (SDO)
5-Gender
equality 14-Aquatic life

Distribution of hours
Total: 24
Magistrates: 20
Directed work: 4

Language(s) used during the course: French

Elective modules

Menu 3 - Sensors, principles and implementation

Prerequisites: Electronic basics

Learning Objectives

The sensors are multiple and affect all areas of measurement and instrumentation; their diversity often makes their choices difficult to establish.
The ambition of this teaching is to enable the engineer to identify relevant criteria to guide the choice of a sensor and its electronic environment (conditioner) from a specification; the environment and the operation of sensors will be developed and studied in practical work.

Description of the programme

The aim of this teaching is to take an interest in the use of a physical phenomenon to generate usable information in the context of a process control.

Notions discussed:
- Metrological characteristics of sensors (influence quantities, errors in measurement, sensor calibration, limits of use, sensitivity, speed, response time...)
- The different physical principles used for the design of sensors
- Passive sensors fs and active
sensors- Conditioning of the signal for passive and active
sensors- Sensors treated according to their applications (temperature, pressure, position...)
- Practical study of a system with sensors of different types

Target generic centrale-specific field-related skills and knowledge

- Mastering the complexity of systems
- Developing technical and scientific innovations.
- Solving complex
problems - Solving transdisciplinary problems requiring the introduction of process control

Knowledge Control Procedures

Personal work: Written Statement/Render (50%)
Project: Reporting (50%)

Bibliography

Documents constructors

Sensors in industrial instrumentation (Dunod. G.Hasch)

Teacher

- Alain Kilidjian

Sustainable development objectives (SDO)

3-Access to Health
6-Access to safe water and sanitation
9-Building Resilient Infrastructure
11-Sustainable cities and communities
12-Responsible consumption and production

Distribution of hours

Total: 30
Magistrates: 10
Directed work: 4
Practical work: 16

Language(s) used during the course: French

Elective modules

Menu 2 - Digital servo

Prerequisites: Continuous linear systems automation

Learning Objectives

In addition to the lessons in electronics and linear automatic to approach the study of systems and their digital control.
Students will be able to participate in the development of a specification and the design of control systems to control processes (mechanical, electronic, chemical...) by implementing an algorithm in a calculator.

The student will be able:
- To use the Z-transformed to study stability in closed loop of a stable or unstable system in open loop and interpret the specification on static and dynamic
constraints - Write the control algorithm of the system to be controlled

Description of the programme

A description of the methods of synthesis of numerical control laws that ensure the dynamic and static behaviour of a system in accordance with constraints described in a specification. Polynomial methods: Methodologies and implementation on a calculator.

The 3 developed parts are as follows:
- General concepts and mathematical
tools- Methods of studying stability and precision
- Methods of synthesis of

digital regulatorsTheoretical concepts will be illustrated in TL by the implementation and simulation of multi-physical systems and their associated control/command.

Target generic centrale-specific field-related skills and knowledge

- Mastering the complexity of systems
- Developing technical and scientific
innovations - Solving complex
problems - Solving transdisciplinary problems requiring the introduction of process control

Knowledge Control Procedures

Practical work:
Oral and
reporting

Bibliography:

Course documents.

Terminal, P., *Analysis and Regulation of Industrial Processes Volume 2.*

Roland Longchamp, *Digital Dynamic Systems Command.*

Teaching team:

- Alain Kilidjian
- Guillaume Graton

Sustainable development objectives (SDO)

4-Access to quality education
5-Gender equality
7-Use of renewable energy
12-Responsible consumption and production

Distribution of hours

Total: 30
Magistrates: 12
Directed work: 6
Practical work: 12

Language(s) used during the course: French

Training

Prerequisites:
Quantum Physics Course 1A

Learning Objectives
These three days are meant to "dig" and shed new light on the two bones of modern physics in the twentieth century: quantum theory and relativity(s) through different approaches:
- Bibliographic and presentation work "tagged" on the 1st day (relativity(s)
- Practical coding work Matlab on the 2nd day (quantum)
- Bibliographic and exploratory work freer on the 3rd day (choice: quantum and/or relativity)

Description of the programme
The first day will be devoted to the genesis of relativity(s). Essentially, the students will work in small groups on the development of prerelativistic concepts in the nineteenth century, in particular on the quest for light ether which led to the theory of special relativity at the beginning of the twentieth, and also on the concept of black hole in relation to the description of light in terms of particles, which prefigures both the quantum revolution and relativity This work
will be done on the basis of documents provided to the students and will be evaluated through a presentation.

The second day aims to illustrate basic concepts of the 1A Quantum Physics course (e.g. 1D systems, potential wells, double wells, harmonic potential, etc.) through specific Matlab codes.

The third day will be devoted to an all-round bibliographic exploratory work , with a great freedom for the student to choose the subject, while remaining connected to the main subjects, namely quantum (example: recent developments related to the Quantum Plan in France) and relativity (example: detection of gravitational waves and observation of black holes).

Target generic centrale-specific field-related skills and knowledge
- C1 Scientific and technical innovation: The student will be • to develop new skills and in particular to "dig" the basic concepts of modern physics. The second day (quantum codes) will allow students to develop new technical skills (Matlab).
- C2 Maî thrice of complexity é systems è. The message of the first day is to show that a scientific revolution does not take place in one day, but is built through a complex process that is highly non-linear, bristling with trapdoors and dead ends.
- C5 strategic vision. On the third day, the student will be • to explore a developing scientific field, which will contribute to the development of his or her strategic vision.

Knowledge Control Procedures
- CC1: oral presentation and written report of the 1st day
- CC2: written report on the 2nd day
- CC3: oral presentation and written report of 3rd day

Bibliography
Different types of documents will be provided and/or selected as part of the bibliographic work. Copies and codes provided for the Practical Work.

Teacher
- Thomas Durt

Distribution of hours
Total: 24
Magistrates: 6
Directed work: 6
Practical work: 6
Projects: 6

Language(s) used during the course: French

Elective modules

Menu 2 - Analysis and processing of biomedical signals

Prerequisites: No

Learning Objectives

To enable the general engineer to identify issues that may be relevant to signal and image processing for biomedical, and to provide the essential elements for the extraction, processing and representation of information. Acquire the principles of a scientific approach and new and specific techniques for the treatment of biomedical signals. Master the techniques of processing, analysis and interpretation.

Description of the programme

The study of biomedical signals and images is a special area of signal processing. The treatment of biomedical signals is a discipline that has undergone significant development in recent years. Diagnostic aid using signal processing tools plays a key role in medical progress. This course will focus on the fundamental aspects of the extraction, processing and representation of information contained in signals.
It is a question of discovering some basic techniques used for the modelling and analysis of biological signals and images based on concrete examples of the application of these techniques to the needs of the medical environment (electro-encephalogram, electrocardiogram, magnetic resonance imaging, nuclear imaging...). Use, but also adapt, various techniques, such as filtering, spectral analysis, time-frequency analysis, estimation, pattern recognition, etc., in order to make the best use of these techniques for the intended applications.
Workshops on the use of simulation and analysis software will aim to illustrate the theoretical content of the course using real and/or simulated data.

Target generic centrale-specific field-related skills and knowledge

- Learn to question the choice of methods
- Master the basic principles of modelling and analysis
- Master the complexity of the systems and the problems encountered
- Take a strategic vision and know how to implement it

Knowledge Control Procedures

Continuous monitoring: an average of accounts and writings

Bibliography

Course materials

Teacher

- Salah Bourennane
- Caroline Fossati

Sustainable development objectives (SDO)

13-Combating climate change
14-Aquatic Life
15-Earth Life

Distribution of hours

Total: 30
Magistrates: 24
Directed work: 6

Language(s) used during the course: French

Common Trunk

Deepening Mathematics, Computing and Economics

Prerequisites: No

Learning Objectives

MIE is a 72-hour course (54 hours of courses and 18 hours of autonomy) that brings together Mathematics, Computer Science and Economics courses.

It is composed of three times, four weeks each (18 hours of courses and 6 hours of autonomy). For each time, the student follows an EU of Math, Info or Eco. After the 3 times, however, each student must have made at least 2 different subjects out of the 3 proposed.

Description of the programme

Choosing an EU of Math, Info or Eco per time

EU of Math:
Time 1: probabilities/statistics

Time 2: variational approaches, finite elements

Time 3: introduction to Info's optimal transport theory

EU Info:
Time 1: web server

Time 2 data driven programming

Time 3: scientific python

EU Eco:
Time 1: strategic behaviours: game theory
Time 2: innovation and market power: monopoly and annuities

Time 3: inequality: economic data and policies

Knowledge Control Procedures

Continuous control.

Teacher

M1: christophe.pouet@ec-m.fr,
M2: guillaume.chiavassa@ec-m.fr and jacques.liandrat@ec-m.

frM3: magali.tournus@ec-m.fr
l1: francois.brucker@ec-m.fr
l2: emmanuel.dauce@ec-m.fr
l3: muriel.roche@ec-m.fr
E1: renaud.bourles@ec-m.f
rE2 and E3: nicolas.clootens@ec-m.fr

Distribution of hours

Total: 72
Magistrates: 54
Applied Jobs: 18

Language(s) used during the course: French

Elective modules

Menu 1 - Telecommunications

Prerequisites: No

Learning Objectives
At the end of this course, the student is able to understand the concepts of information and their usefulness for coding and telecoms, master the basic principles of optimising telecommunications processes, learn to question the choice of system, methods and architecture, and learn to integrate processing methods into reliable and cost-effective hardware architectures. It will also be able to provide a strategic vision and know how to implement it.

Programme Description
Technological demand and economic pressure have driven telecommunications systems towards the development and use of the most advanced methods for their design, operation and maintenance. The common objective is the transmission and processing of information: these systems are available in many forms, more or less close to the end user. The information flow has taken centre stage in this field, the visible face of which is the development of the Internet and very high speed, but to which we must add the new generations of database backup systems. This teaching is mainly aimed at exploring several aspects (information theory, estimation, detection...) related to telecommunications and their evolution. It provides an understanding of the fundamental mechanisms of telecommunications: know the best systems and devices available for transmitting, transmitting and receiving a signal or information, select the techniques for processing that signal or information to optimise these operations, and know how to integrate these methods into reliable and cost-effective hardware architectures.

Target generic centrale-specific field-related skills and knowledge
To enable the general engineer to identify the issues that may be relevant to signal processing and information theory for telecommunications, and to provide him with the essential elements of this field which constitutes one of the foundations of digital technologies. Acquire the principles of a scientific approach and the new and specific techniques whose industrial and societal applications are expanding rapidly.

Knowledge Control Procedures
Continuous monitoring: average report and writing

Bibliography
L.L. Scharf, *Statistical Signal Processing - Detection, Estimation and Time Series Analysis*, Addison-Wesley, 1991.
H. Van Trees, *Detection, Estimation and Modulation Theory*, John Wiley and Sons, 1968 (volumes

1, 2 and 3).
G. Battail, *Information Theory - Application to Communication Techniques*, Masson, 1997.

Teacher
- Salah Bourennane

Sustainable development objectives (SDO)
11-Sustainable cities and communities
13-Combating climate change
15-Earth Life

Distribution of hours
Total: 30
Magistrates: 24
Directed work: 6

Language(s) used during the course: French

Elective modules

Menu 2 - Introduction to stochastic processes

Prerequisite

Undergraduate level probability courses (3rd year of Licence, MAT-1A).
Matrix calculation.

Learning Objectives

1. The student will be able to use conditional hope in different branches of probability.
2. The student will be able to model a number of phenomena through appropriate stochastic processes.
3. The student will be able to recognise the main stochastic processes in discrete time and exploit their properties to give qualitative or quantitative elements regarding their long-time behaviours.

Description of the programme

The aim of this course is to prepare students to take advanced courses in probability, such as a stochastic calculus course that is the basis of financial mathematics or a course of stochastic algorithms that are very present in Statistics, Data Science and Machine Learning.
This 30-hour course is divided into:
- 7 Lectures: (2h each) = 14h
- 5 Directed work: (2h each) = 10h
- 3 Practical work: (2h each) under Python = 6
hThe programme covered in this course is as follows:
1. Conditional
hope, conditional law2. Filtration, stopping time, player ruin, identity of Wald
3. Martingales in discreet time, stop theorems, convergence theorems of martingales (Lp, almost surely)
4. of Markov on countable state spaces, strong Markov property, recurrence, positive recurrence, ambiguity
5. Fish process: construction, strong Markov property, characterisation
6. Marovian jumping process: definitions

Target generic centrale-specific field-related skills and knowledge

1. Calculate the conditional expectancy of a random variable using its conditional law or the properties of conditional hope (linearity, measurability, independence).
2. Verify that a stochastic process is a martingale and determine whether the process converges.
3. Recognise a situation that can be modelled by a Markov chain, understand the property of strong Markov, know how to classify Markov chains according to their behaviour.
4. Recognise a situation that can be modelled by a Fish process and more generally by a Marovian jumping process.

Knowledge Control Procedures
CC1: writes 100%

Bibliography
The bibliography will be given at the beginning of the course.

Teacher
- Charles Bordenave (CNRS DR., I2M Probabilities Team)

Distribution of hours
Total: 30
Magistrates: 14
Directed work: 10
Practical work: 6

Language(s) used during the course: French

Common Trunk

Mecha-Physical Deepening

Prerequisite:

EU 1A/Mechanical: 1A/
Physical MMCUE basics: physical, statistical and
quantum physicsEU 1A/Waves and Signal: Maxwell, wave and Helmholtz equations, paraxial propagation, simple optical systems,
signal processingBases of group theory

Learning Objectives

- Use the 1-year programme to discover the fundamental
notions - in dynamics, for mechanics
- on the formation of images and the transmission/obtaining of information using light, for optics
- on the concept of symmetry and on the variational calculation in connection with the formalisms of Lagrange and Hamilton, for quantum
physics - on fluctuations and phenomena critical to statistical
physics - Know how to put a problem in equations using different tools
- Know how to calculate theoretically or numerically the solutions of the various problems formulated
- Know how to analyse the solutions obtained

Description of the programme

The programme is divided into three parts of equivalent volumes: Mechanical, optical and physical (quantum and statistical).
Mechanical:
- Equation tools:
- Theorem of virtual powers and opening to the method of finite elements

- Hamilton principle and Lagrange equations

- Resolution and analysis:
- Transient and stationary regimens

- Modes
- Stability and bifurcations

Optical:
- Frequent spectra and propagation of Fresnel

- Matrix methods for rays and waves, Collins formula and phase space

-Picture forming systems, afocals and Fourier transformers

- Wave guides (metallic, dielectric and index gradient)

- Temporal aspects: phase and group speeds, dispersion, propagation of gaussian impulses

- Uncertainty relationship

- Lasers: stimulated emission, coherence, cavities, modes, short pulses, amplification of chirps

Quantum physics:
- Infinitesimal symmetries, algebra of Lie of generators: Lorentz group, spinal transformations of the SU2 group seen as a representation of the rotations group in R3
- Density matrix for qubits (Bloch vector), coherence and purity of a quantum state, links with optics
- Principle of lesser action

Statistical physics:
- Theory of distributions and applications in physics
- Random fields applied to physics
- Balance Fluctuations and Phase Transitions

Target generic centrale-specific field-related skills and knowledge

- Knowledge of the links and similarities between different disciplines
- Knowledge to equate a large number of complex systems - Knowledge to solve an equations system analytically
- Knowledge to the foundations of the numerical methods of solving the systems encountered
- Knowledge to analyze the solutions obtained

Knowledge Control Procedures

CC1: (42%)
CC2: (42%)
CC3: Optical mini-project (8%)
CC4: mini-tests at the beginning of Directed Mechanical Works (8%)

Bibliography

Course materials in
PFPhysics:
D. Griffith, *Introduction to Quantum Mechanics, Wiley* (available in electronic and paper version at the documentation centre).
Ph. Réfréger, *Noise theory and application to physics*, Springer, 2003.
J.M. Yeomans, *Statistical Mechanics ics of Phase Transitions*, Oxford Science Publications, 1992.

Teacher

- Miguel Alonso (optical)
- Thomas Durt (quantum physics)
- Philippe Réfréger (statistical physics)
- Emmanuelle Sarrouy (mechanical)

Distribution of hours

Total: 72
Magistrates: 36
Directed work: 20
Practical work: 2
Applied Jobs: 10
Other: 4

Language(s) used during the course: French

Elective modules

Menu 3 - Semi-Conductor Materials, Properties and Applications

Prerequisites: No

Learning Objectives
Knowledge of the basic physical processes involved in the operation of semiconductor components (strip structure, state densities, load carrier distribution, mobility, generation/recombination, etc.), the operation of the basic components (different types of junction, light emitting diodes, photovoltaic sensors).
Implement this knowledge to understand and scale applications in the field of photonics on the basis of scientific, technological and economic considerations.

Description of the programme
Semiconductors are present in most of the modern electronic and optoelectronic devices you use. They have a dual complex function that allows them to have the properties of a driver, and the properties of an insulator, according to the conditions of use. This elective aims to teach the basic elements of semiconductor physics and especially light-to-material interactions in these materials, to address their most common applications in the field of light generation and detection (telecoms, lighting, photovoltaics).
The course is divided into 3 parts:
- Part 1: Introduction to Semiconductor Materials and Basic Components (8 hours of course, 2 hours of Directed Work). Crystalline structure - electronic states in semiconductors - distribution of load carriers - equilibrium SC/out-of-equilibrium SC - different types of junctions
- Part 2: Photon interactions - semiconductor, light emitting diodes (8 hours of course, 2 hours of Directed Works). Generation, recombination, charge injection - photon/semiconductor interactions - light emitting
diodes - Part 3: Photovoltaic, resources to the latest developments (8 hours of courses, 2 hours of Directed Works). Solar deposit, mineral, organic photovoltaic technologies and the latest developments - Directed works: cell properties and sizing

Target generic centrale-specific field-related skills and knowledge
The skills and knowledge sought are those of scientific and technical innovation,
which aims to develop the basis of scientific and technical knowledge of the Central Engineer, especially in the fields related to high-tech. Semiconductor technologies
are at the heart of all electronic systems. Understanding the basis of their operation is essential to managing the complexity of systems. The resulting technological innovations address the need to create value through scientific and technical innovation.

Knowledge Control Procedures
2h review

Bibliography

B. E. A. Saleh, M. C. Teich, *Fundamentals of Photonics*, 2019, Ed. John Wiley & Sons, Inc.
J. Hladik, *Renewable Energy Today and Tomorrow*, 2011, Ellipses.
J. Bernard, *Solar Energy - Calculations and Optimisation*, 2011, Technosup, Ellipses.
A. Labouret and M. Villoz, *Solar Energy* Dunod, 2009.

Teaching team:

- Laetitia Abel-Tiberini
- Caroline Fossati
-Laurent Gallais-During

Sustainable development objectives (SDO)

7-Use of renewable energy
9-Building Resilient Infrastructure

Distribution of hours

Total: 30
Magistrates: 24
Directed work: 6

Language(s) used during the course: French

Common Trunk

Thematic project

Prerequisites: No

Learning Objectives

At the end of the learning unit, participants will have an understanding of the strategic and operational activities of the management of innovative projects:
More specifically, participants will be able to:
- Develop a project charter and the associated project plan (framing)
- Define a management plan, which details the organisation and communication with all the project stakeholders (framing)
- Define the activities, the relations and the duration of activities to develop project schedule (planning)
- Manage project resources (financial, material and human), anticipate and correct project risks - Monitor project progress, results and remedial actions - Complete/complete project and ensure appropriate transfer

Description of the programme

This EU includes 1 module:
- Project: The project starts in September and closes in January. During this project, students will learn how to master project definition and framing, planning, project organisation, project management and closing. In addition to what they have acquired in the EU Innovation Project, they will gain a more detailed understanding of the human dimension of project management (team work, conflict management, communication, organisation, behavior). To do this, many milestones will have to be passed and many deliverables will have to be completed and validated by the tutors during the Formulation, Framing, Planning, Execution, Transfer phases.

The evaluation of skills will take place through the different phases of the project and associated deliverables:
- Formulation: V0 Project Briefing Sheet, Roles and Responsibilities
- Framing: Management plan, contract document, communication plan, operating mechanisms

- Planning: WBS/OBS, Planning, Risk Analysis

- Execution and Mapping: dashboard, project review, logbook
- Transfer: Project deliverables, report, support each phase will be closed by the completion of a milestone: either written or oral presentation.
The tutors will also be present as well as the juries to validate the acquisition of the skills.

Target generic centrale-specific field-related skills and knowledge

- C1 Scientific and technical innovation: Identification of needs, exploration and state of the art of the existing, proposal of solutions addressing the problem
-C2 Control of complexity and systems: complexity resulting from technical solutions, complexity resulting from constraints, identification of problems and their resolutions
- C3 Programme direction: Technical aspects (needs analysis, project design and monitoring) with organisational aspects (stakeholders, communication)
- C4 Human management: all aspects of team management (role of project manager, members, and coordination of actors)
- C5 Strategic Vision: define a localised strategy and subordinate its operational decline

Knowledge Control Procedures

Continuous monitoring:
- Interactions with your tutors (10%)
-Mid-Term Support (10%)
- Intermediate Deliverables (10%)
-Final Deliverables (25%)
-Project Completion Report (20%)
-Final Support (25%)

Bibliography

Project Management Institute (2009), Guide to the Body of Knowledge in Project Management, Project Management Institute, 4th
editionBrun, J-P. (2013), *Team Management: 7 levers to improve well-being and efficiency at work, Eyrolles, 2nd edition*

Teaching team:

- F. Magnani
- A. Soric

Sustainable development objectives (SDO)

4-Access to quality education
8-Access to decent jobs
12-Responsible consumption and production

Distribution of hours

Total: 48
Projects: 48

Language(s) used during the course: French

Elective modules

Menu 3 - Microcontrollers and their environment

Prerequisites: No

Learning Objectives

The purpose of this option is to introduce you to and familiarise yourself with the operation and use of microcontrollers, which have become essential electronic components in electronic and automated systems, especially embedded systems.
Apprehend a complex system of sensors and actuators for the Internet of IoT connected objects.

Description of the programme

You will understand the architecture of a microcontroller system and be able to write a programme in assembler or advanced language to implement a microcontroller.
You will understand the various functions such as acquisition of signals, creation of analogue signals for systems control, transmission of signals under different protocols, etc. in various applications of robotic type, control of automated systems, home automation, automotive, aeronautics ...
We will explain how to operate a microcontroller within your real electronic systems in robotics, control of acquisition system, 3D printer, automation. We will link this course to all other training courses and will actually implement signal acquisition and system control.
To be truly comprehensive, the course will include a part on the design of microcontrollers and the different technologies used to create them.
The option will be based on courses, and essentially on the practice of designing and piloting maps on topics that you can choose and that can be derived from your associative or personal projects.
You will be able to programme an embedded system on a kit you choose based on Arduino, Raspberry components...

At the end of the course you will be able to describe, understand, choose and programme a microcontroller hardware and implement it within a specific system and application.

Target generic centrale-specific field-related skills and knowledge

Create value through scientific and technical innovation through the innovations used in IoT and embedded and communicating electronics:

- Mastering the complexity of systems through the electronic system that responds to a complex problem
- Lead programmes by managing the Practical/Project session series
- Ethically and responsibly managing a problem by responding to an electronic system that is ethically responsible

Knowledge Control Procedures
Assessment of the model carried out, its operation, the programming and the method used.

Bibliography
Course slides.
Documents of components such as Arduino, Raspberry.

Teacher
- Thierry GAIDON
- Caroline FOSSATI

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: 30
Magistrates: 14
Directed work: 8
Practical work: 8

Language(s) used during the course: French