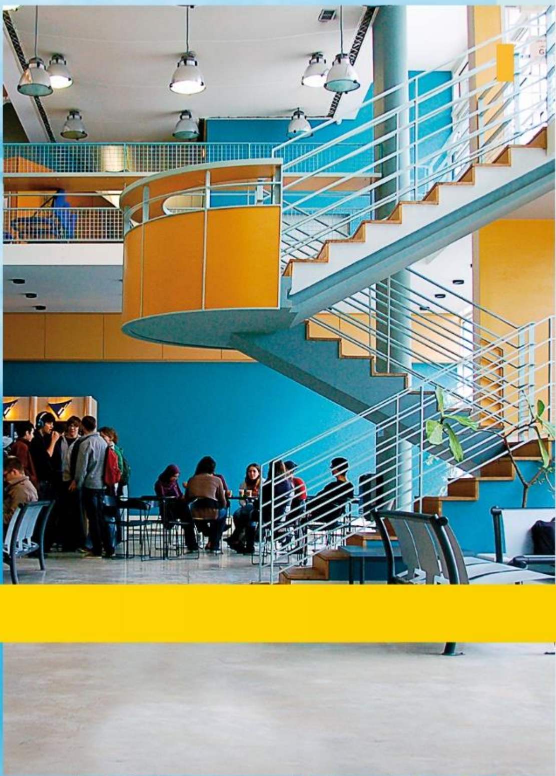

POLYTECH®
ORLÉANS
School of Engineering of the University of Orléans

Prospectus 2018-19

Courses Syllabus

Polytech Orléans

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Contents

Scientific courses and Syllabus

🏳 : less than 20 % of the course is taught in English - documentation in English provided
🏳🏳 : between 20 and 75 % of the course is taught in English
🏳🏳🏳 : more than 75 % of the course is taught in English

Civil and Geo-environmental Engineering (GC)

Course Unit Code	Course Unit Title	Total Hours without ind. work	ECTS Credits
Fall Semester (September – December)			
	Sustainable Construction (COD)		
9CD01	Dynamic and environmental impacts on structures - *Ouvrages sous sollicitations dynamiques et environnementales*	70	8
9CD02	Construction Sites and Project Management - *Chantiers du bâtiment et maîtrise d'œuvre*	112.5	11
9CD03	Thermal and aeraulic buildings - *Thermique et aéraulique des bâtiments*	40	5
	Geoenvironmental Engineering (GEN)		
9GE01	Polluted sites and soils - *Sites et sols pollués*	55	6
9GE02	Water Resource and Environment Management - *Gestion de l'eau et des milieux associés*	72.5	8
9GE03	Design and Depollution Works - *Bureaux d'études et chantiers de dépollution*	46.25	5
9GE04	Site preparation - *Préparation de chantier TP*	48.75	5
	Public Works and Land-Use Planning (TPA)		
9TP01	Urban Design and Planning - *Conception des aménagements*	112.5	12
9TP02	Site preparation - *Préparation de chantier TP*	48.75	5
9TP03	Public Works - *Travaux publics*	61.25	7
Spring Semester (January – March)			
AGC01	Project – *Projet d'entreprise*	170	10

Students have to choose one option and then only pick up courses in this option.

Civil and Geo-environmental Engineering	9CD01	Semestre 9

Dynamic and environnmental impacts on structures

Supervisor: Dashnor HOXHA **ECTS: 8**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Estimate wind and snow loads following Eurocodes
- Analyze behavior of structures under dynamic loads
- Design structures/buildings in seismic zones following Eurocodes 8
- Characterize soil-structure interactions, design underground structures
- Design foundations of bridges and special foundations
- Quantify the impact of environnemental agents on structures

Teaching Process (syllabus)

Assessment of wind and snow loads, following Eurocode rules

Analyzes following EN 1991-3 et EN-1991-4 of wind and snow loads, design practice, simplified and computer-based models

Dynamics of structures

- SDOF, free and forced vibrations, harmonic, periodic and arbitrary dynamic loads, transfer function
- MDOF : modal analysis, Rayleigh quotient, Ritz vectors

Earthquake design of buildings

- Eurocode 8 for design of buildings : lateral force method, modal analyses, classes of behavior
- Eurocode-Compliant Seismic analysis
- Seismic retrofitting of existing structures

Soil Structure interactions

- Bases of soil-structure interaction
- Design of supports for underground constructions
- Foundations, deep foundations, special foundations under dynamic solicitation

Assessment of environmental impact on structures

- Ageing of concrete structures, case studies
- Monitoring of ageing, methods of reparation and renovation
- Stone ageing ,characterization and reparation

Assessment Mode

Written exams, project reports

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
42.5h	8.75h	18.75h			**70h**

Proportion of the TU in English: ⚐⚐

Civil and Geo-environmental Engineering 9CD02 Semester 9

Construction Sites and Project Management

Supervisor: Naïma BELAYACHI **ECTS: 11**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Plan a construction site;
- Manage a construction site financially;
- Plan construction for a specific project;
- Manage human resources according to the construction scheduling;
- Manage materials and equipment;
- Study the economic aspect of construction;
- Assess risks, comply with safety regulations;
- Read and analyze project requirements and documents;
- Read construction drawings, analyze their structure and dimension the steel reinforcement;
- Study the rehabilitation of a building according to seismic, thermal regulation; suggest reinforcement for a given structure;
- Find building sustainable solutions (building waste, bio-sourced insulation materials, organic concrete).

Teaching Process (syllabus)

- Analyzing tender enquiries
- Identifying a building operation boundaries and interfaces
- Identifying construction modes and organizational methods used to plan a construction site
- Assessing environmental impact
- Calculating material quantities (quantity surveying)
- Introducing different technical constraints and suggestion of technical and economic variants
- Managing an actual project and calculation of structures in implementation phases (project teaching)
- Dimensioning the elements of a structure made of reinforced concrete in both average and accidental (seism) situations, application of earthquake-resistant building regulation
- Sustainable bioclimatic design and thermal rehabilitation
- Dimensioning of wooden structures. Dimensioning of wooden joints and sections. Technology of wood.

Assessment Mode

A report and oral defense for each design office project; an exam on construction sites and wood structures

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
55h	31.25h	26.25h	23.75h		**112.5h**

Proportion of the TU in English: ⚐⚐

Civil and Geo-environmental Engineering **9CD03** **Semester 9**

Thermal and aeraulic buildings

Supervisor: **Marwen BOUASKER** **ECTS: 5**

Learning Outcomes

At the end of this teaching unit, the student engineers will be able to :

- Know the heat transfer modes
- Design a solar thermal collection system
- Apply the different thermal standards
- Establish the thermal balance of a room
- Design a ventilation network
- Design an air treatment battery

Teaching Process (program)

Thermal building insulation

- Sustainable energy
- Solar capture systems
- Thermal losses in a building
- Heat balance of a room
- Application of labels and thermal standards
- Condensation at the surface and in the mass of a wall

Aeraulic

- Characteristic equations of ducted air flows
- Calculation of air ducts
- Fan selection (constant j method, static pressure gain method)
- Aeraulic exchanges and condensations
- Air treatment

Assessment Mode

2 exams : 1 exam on thermal building insulation and 1 exam on aeraulic

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
18.75h	21.25h				**40h**

Proportion of the TU in English: ⚐⚐

Civil and Geo-environmental Engineering 9GE01 Semester 9

Polluted sites and soils

Supervisor: Mikael MOTELICA **ECTS: 6**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Understand biogeochemistry of natural media
- Evaluate and model the behavior of key-pollutants in environmental compartments
- Design innovative remediation strategies (physical, chemical and biological) for polluted sites and soils (PSS)

Teaching Process (syllabus)

Geochemistry of contaminants

- Introduction to environmental geochemistry
- Geochemistry of surface waters
- Geochemistry of groundwaters
- Biogeochemistry of soils
- Hydrogeochemical modelling
- Pollution chemistry
- Ecodynamics of contaminants

Contaminated sites and soils diagnosis

- Diagnosis PSS
- Measurement and prediction of pollution (waters)
- Measurement and prediction of pollution (soils, sediments and wastes)
- Diagnosis and decontamination of hydrocarbons
- Diagnosis and decontamination of metals and metalloids
- Physico-chemical treatments
- Bioremediation
- Phytoremediation

Assessment Mode

A report for part 1 and a report and oral defense for each project for part B

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
35h	15h	5h			**55h**

Proportion of the TU in English: ⚐⚐⚐

Civil and Geo-environmental Engineering   9GE02   Semester 9

Water Resource and Environment Management

Supervisor: Christian DÉFARGE   **ECTS: 8**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Consider risks in land-use planning (floods…) and water management (living organisms…)
- Implement hydrogeological methods in the field (flow, piezometric map, pumping test…)
- Model water and pollutant transfer in surface and underground hydrologic systems
- Size, implement, pilot and evaluate water and wastewater treatment processes and plants

Teaching Process (syllabus)

Geobiology of resources and processes

- Living organisms present in water, bioindicators, biological water-related diseases, invasive species
- Roles of living organisms in natural waters and environments, use in water treatment processes

Vulnerability, risks

- Risk management chain: uncertainty/issues, security/protection, forecasting, damage repair
- Study of dangers and crisis management
- Principles and methods for the prioritization of water resource vulnerability and GIS application of the indicator-based approach

Field hydrology

- Flow measurement via exploration of the velocity field exploration and chemical gauging
- Drawing up a piezometric map and delimitation of the system
- Well-production test to characterize the hydrodynamic properties

Water management

- Notions of hydrological cycle, residence time and groundwater storage volume
- Interaction between reservoirs, mixing, tools for active resource management using hydrodynamic modeling (Modflow software)
- Mass transfer mechanisms, at pore level and at the macroscopic level, pollutant reactivity

Water and wastewater treatment

- Classroom lessons: Water and wastewater treatment processes and plants, case studies
- On-site lessons: Drinking water production plants (ultrafiltration, iron and manganese removal, etc.), urban and industrial wastewater treatment plants (activated sludge, biological filters, etc.)

Assessment Mode

Reports on case studies and field work

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
45h	27.5h		12.5h		**72.5h**

Proportion of the TU in English: ⚐⚐

Civil and Geo-environmental Engineering 9GE03 Semester 9

Design and Depollution Works

Supervisor: Christian DEFARGE **ECTS: 5**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Conduct an environmental impact assessment
- Realize artificial tracer tests and interpretations
- Proportion devices for active management of aquifers and pollution mitigation
- Conduct projects and works in soil remediation

Teaching Process (syllabus)

Environmental impacts

- Impact assessments strictly speaking on the themes of field geology and water management and a specific topic such as public easement or dusts
- Hazard assessment
- Simulation of the activity of an environmental engineering consultants: study in groups of an environmental impact assessment for a quarry's operation

Artificial tracer tests applied to engineering

- Practice of artificial tracer tests (sizing, installation and implementation, spectrofluorimetric detection, concentration-time curve)
- Synthesis and data interpretation in the karstic environment of the Val d'Orléans, report writing
- Case studies on tracer tests applied to design of depollution processes

Soil remediation works

- Alternating between classes and home work around a concrete case for understand:
  What is a remediation project? The needs of a client? How to build a remediation strategy? How to choose and size a remediation technology?
- Monitoring of a remediation project
- Elements of remediation project management

Assessment Mode

Case studies and field work reports

Workload

Lectures	Classes	Labs	Individual work	Project work	STUDENT WORKLOAD
28.75h	17.5h				**46.25h**

Proportion of the TU in English: ⚐⚐

Civil and Geo-environmental Engineering	9GE04	Semester 9

Site preparation

Supervisor: **Laurent JOSSERAND** **ECTS: 5**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Master main geophysics tests, their implementation conditions and their fields of applicability in civil engineering;
- Identify pollutants in a polluted soil and measure the degree of pollution;
- Make diagnoses of a site pollution and study remediation methods (Learning Outcome 3).
- Propose technical solutions for a site deconstruction or dismantling an industrial site

Teaching Process (syllabus)

This TU is divided in two main parts. The first one deals with geophysical in-situ tests, like resistivity, seismic. These tests will allow us to obtain datas on geological layer.

The second one deals with Polluted site management method (Typology of pollution, regulations and hazards, stakeholders, inventory and database), Diagnosing pollution (Geochemistry of pollutants in soils and aquifers, impact of pollution, methodological tools), Measuring and predicting pollution (Sampling, sampling techniques, identifying the dominant parameters, in situ measurements, methods of analysis), Physical and biological pollution control, remediation of polluted sites

Assessment Mode

Classes assessments, reports, individual assessments and synthesis reports

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
25h	13.75h	10h	9h		**48.75h**

Proportion of the TU in English: 🏳🏳

Civil and Geo-environmental Engineering **9TP01** **Semester 9**

Urban Design and planning

Supervisor: **Xavier BRUNETAUD** **ECTS: 12**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Design load-bearing structures and foundations for small engineering works according to site data and the work specifications;
- Understand the transportation issues at stake in urban environments, the main modes of transportation and the associated infrastructures as well as their planning and design techniques.
- Design and compute a pavement structure according to specifications (traffic), given supporting soil and climate environment;
- Design and dimension the rainwater and wastewater sewer system including associated storage basins;
- Draw a linear infrastructure (road, railroad) using Mensura software;
- Calculate the geometry of structural elements.

Teaching Process (syllabus)

Engineering works

Specifications, site and regulation data. Load-bearing structure design: foundation design and calculation. Overview of the main types of bridge design.

Transport infrastructures

Urban transport map, urban planning. Pre-DUP studies. Exclusive lanes for public transport. Rail infrastructures.

Pavement dimensioning

Revision of the French dimensioning method principles using Alizé software. Case studies (Alizé).

Sewer systems design and dimensioning

Revision on hydraulics and Mensura software. Case studies on actual rainwater / wastewater projects using Mensura.

Road alignment

“Alignments” drawing on Mensura. Implementation of an alignment project on Mensura.

Structural design

Calculation of the structural elements of reinforced concrete, prestressed and metallic structures. Application of seismic codes

Assessment Mode

Construction of a model of bridge, written exams, projects reports.

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
63.75h	16.25h	32.5h	16.25h		**112.5h**

Proportion of the TU in English:

Civil and Geo-environmental Engineering	9TP02	Semester 9

Site preparation

Supervisor: **Laurent JOSSERAND** **ECTS: 5**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Master main geophysics tests, their implementation conditions and their fields of applicability in civil engineering;
- Identify pollutants in a polluted soil and measure the degree of pollution;
- Make diagnoses of a site pollution and study remediation methods (Learning Outcome 3).
- Propose technical solutions for a site deconstruction or dismantling an industrial site

Teaching Process (syllabus)

This TU is divided in two main parts. The first one deals with geophysical in-situ tests, like resistivity, seismic. These tests will allow us to obtain datas on geological layer.

The second one deals with Polluted site management method (Typology of pollution, regulations and hazards, stakeholders, inventory and database), Diagnosing pollution (Geochemistry of pollutants in soils and aquifers, impact of pollution, methodological tools), Measuring and predicting pollution (Sampling, sampling techniques, identifying the dominant parameters, in situ measurements, methods of analysis), Physical and biological pollution control, remediation of polluted sites

Assessment Mode

Classes assessments, reports, individual assessments and synthesis reports

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
25h	13.75h	10h	9h		**48.75h**

Proportion of the TU in English: 🏳🏳

Civil and Geo-environmental Engineering 9TP03 Semester 9

Public Works

Supervisor: Laurent JOSSERAND **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Define the schedule of quantities for a construction site; optimize its tasks and organization. Through productivity, they will be able to estimate its duration, cost and environmental impact limited to greenhouse gases.
- Choose and optimize quantities of materials necessary to construction sites among which stones, soils, pipes, coated materials... Acquired knowledge about these hydrocarbon coated materials and their bonding agents will allow students to optimize their compositions;

Teaching Process (syllabus)

This TU is the logical consequence of “Road and building Construction” 8GC02. Many implementation projects allow students to deepen their knowledge and skills while giving them the opportunity to get prepared for their future professional position:

- construction sites, study of economical variants or solutions with a limited environmental impact,
- use of natural stones,
- implementation of networks (wastewater, rainwater, multitubular network, etc.),
- specific coated materials (HiMA, draining and aeronautical asphaltic concrete, etc.),
- road recycling.

Assessment Mode

Classes assessments, reports, individual assessments and synthesis reports

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
31.25h	22.5h	7.5h	7.5h		**61.25h**

Proportion of the TU in English:

Civil and Geo-environmental Engineering **AGC01** **Semester 10**

Project

Supervisor: **Naïma BELAYACHI** **ECTS: 10**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Conduct a study to solve an industrial or research issue using an engineering approach;
- Develop and consolidate disciplinary skills acquired during the three-year training;
- Set a bill of specifications and schedule tasks;
- Perform regular follow-up with the actors of the project, plan follow-up meetings;
- Work autonomously;
- Synthesize the progress made and present them in a written report and oral presentation.

Teaching Process (syllabus)

- Project and format selection (solo, duo or group work)
- Establishment of contact with the limited partner of the study (company or laboratory)
- Writing of the bill of specifications submitted to the limited partner for approval
- Task scheduling and follow-up meetings
- Identification of the tools and resources necessary to the project conduct
- Risk analysis and fallback solutions
- Technical realization of the study
- Update of the project follow-up and implementation of fallback solutions if required
- Delivery of a synthesis report
- Oral presentation of the results of the study

Assessment Mode

Report and oral defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
				170h	**170h**

Proportion of the TU in English: ⚐⚐⚐

Engineering Physics and Embedded Systems (GPSE)

Course Unit Code	Course Unit Title	Total Hours without ind. work	ECTS Credits
Fall Semester (September – December)			
9GP01	Computer vision and Embedded Systems – *Vision & éclairage*	75	8
9GP02	Guided Experiments and Low pressure plasma or Computer vision Engineering - *Spécialisation et projet en photonique, plasma ou objets connectés*	115	16
Spring Semester (January – March)			
AGP01	Project – *Projet d'entreprise*	170	10

The Fall Semester could be complete with a personal project in a lab (see Personal projects)

Engineering Physics and Embedded Systems	9GP01	Semester 9

Computer Vision & Embedded Systems

Supervisors: **Sylvie TREUILLET** **ECTS: 8**

Objectives

On completing this teaching unit engineering students will be able to:

Teaching Process (syllabus)

- Introduction to image processing focused on machine vision, quality control and metrology
- Introduction to geometric vision and embedded vision (calibration, 3D localization), focused on the Smartphone and applications of vision to robotics
- Introduction to object recognition and machine learning

Key Applications

- Industrial vision for quality control (presence / absence, position, counting, character recognition, dimensions, fault detection, sorting, etc.)
- Learning and recognition of objects, video surveillance (pedestrians, vehicle)
- Metrology, Vision for Robotics, Augmented Reality

Assessment Mode

Report and oral defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDIENT WORKLAND**
3,75h		33,75 h		37,5h	**75h**

Proportion of the TU in English: 🏳🏳🏳

Engineering Physics and Embedded Systems **9GP02** **Semester 9**

Guided Experiments and Low pressure plasma or Computer vision Engineering

Supervisors: **Rémi DUSSART** **ECTS: 16**

Objectives

On completing this teaching unit engineering students will be able to:
(Specialization in Plasma engineering)

- Design a plasma reactor for the treatment of materials
- Use and control the lasers and optical systems for the treatment of materials or for the optoelectronics
- Diagnose the plasmas/lasers and characterize the mateirlas after treatment

(Specialization in Embedded Systems)

- Develop some *Smartphone* and *IoT* applications
- Use Linux in the programming of connected objects
- Design systems IHM (Interaction Human Machine)

Teaching Process (syllabus)

Plasma engineering

- General properties of plasmas
- Electric Discharges (DC, RF and microwaves)
- Electrical and Optical diagnosis
- Laser Yag, doubing of frequencies and intensity modulation
- Optical sensors
- Optoelectronics : guidance in integrated photonics and telecommunications
- Guided projects: choice among 4 projects

or

Embedded Systems

- Smartphone as an IoT
- Embedded Linux
- Multithreading
- Ergonomics IHM
- Design software
- Project

Assessment Mode

Report and oral defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
				150h	**150h**

Proportion of the TU in English: ⚐⚐⚐

Exchange student	UP15	Semester 9

Project for exchange student:

Mini research project

Supervisors: **ECTS: 15**

Objectives

Teaching Process (syllabus)

Plasma engineering

Each student joins a research team (GREMI lab) to work on a dedicated project (e.g. plasma etching process, plasma deposition process, plasma diagnostics, microplasmas ...).

or

Computer vision and Embedded Systems

Each student will be involved in the research lab PRISME to work on a dedicated project of signal or image processing, computer vision or embedded systems. Learning by practice and self-learning, using software and existing libraries (imageJ, MATLAB, OpenCV, etc.)

Assessment Mode

Report and oral defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
				150h	**150h**

Proportion of the TU in English: ⚐⚐⚐

Engineering Physics and Embedded Systems **AGP01** **Semester 10**

Project

Supervisors: **ECTS: 10**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Write a product specification based on a requirements analysis
- Establish the functional and technological specifications of a project
- Establish milestones and provide project deliverables
- Manage a project

Teaching Process (syllabus)

Organization:

During this teaching unit, students work on a technical project supervised by a scientific tutor. The project is "full time" from early January to mid-March. It ends with a written activity report, a poster in English and an oral exam

Scientific content:

- The subjects of projects proposed to the student engineers are very varied. We can make a feasibility study of a new concept, design a process for a dedicated application, improve a theoretical knowledge, realize an industrial study, etc ...
- In any case, the student engineer must show his ability to manage a project, to take initiatives, to be able to share tasks (working in pairs), to carry out a technical study in a given time.

Assessment Mode

Written activity report, oral defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
				170h	**170h**

Proportion of the TU in English:

Innovations in Design and Materials (ICM)

Course Unit Code	Course Unit Title	Total Hours without ind. work	ECTS Credits
Fall Semester (September – December)			
9IC01	Business Conferences	10	1
	Materials and structures (MS)		
9MS01	Metallic Materials – *Matériaux métalliques*	55	5
9MS02	Glasses and Simulation of transfers at high temperature – *Verres et simulation hautes températures*	55	5
9MS03	Thematic Scientific Conferences – *Conférences scientifiques thématiques*	10	1
9MS04	Advanced materials and properties/structures/ processes relation – *Matériaux avancés, couplages et procédés*	40	4
9MS05	Ceramics - *Céramiques*	50	4
9MS06	Industrial cases study – *Etude de cas industriels*	55	4
	Mechatronic system modelling (EcoSyM)		
9EC01	Mechatronic systems – *Systèmes mécatroniques*	65	6
9EC02	Analysis and sizing of mechanical systems – *Analyse et dimensionnement de systèmes mécaniques*	55	5
9EC03	Thematic scientific conferences – *Conférences scientifiques mécaniques*	10	1
9EC04	Control strategies and Robotics – *Automatique et robotique*	80	7
9EC05	Collaborative Projects – *Projets transversaux*	55	4
	Multiphysics modelling and simulation (MSP)		
9MP01	Nonlinear mechanics – *Mécanique non linéaire*	70	6
9MP02	Composites and processes – *Composites et procédés*	40	4
9MP03	Multiphysics couplings – *Couplages multiphysiques*	40	4
9MP04	Thematic scientific conferences – *Conférences scientifiques thématiques*	10	1
9MP05	Advanced simulations – *Simulation avancée*	50	4
9MP06	Industrial applications – *Applications industrielles*	55	4
Spring Semester (January – March)			
AIC01	Project – *Projet d'entreprise*	170	10

Students have to choose one option and then only pick up courses in this option.

Innovations in Design and Materials	9IC01	Semester 9

Business Conferences

Supervisors: **Jacques FANTINI** **ECTS: 1**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Have a clearer vision of the different jobs to which the ICM specialty can lead
- Reinforce their professional and personal project
- Better knowledge of industrial applications and their link with the educational content of the business process

Teaching Process (syllabus)

Conferences by experts from the industrial world
Program: to be defined

Assessment Mode

written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
10h					**10h**

Proportion of the TU in English:

This course is available for the 3 options: Materials and structures, Mechatronic system modelling, or Multiphysics modelling and simulation.

Innovations in Design and Materials **9MS01** **Semester 9**

Metallic Materials

Supervisors: **Jacques Poirier** **ECTS: 5**

Learning Outcomes

After this training, the students will be able to:

- Understand the metallurgical concepts necessary for the elaboration, the processing, the properties, the limitations of use of advanced alloys;
- Become familiar with the choice, corrosion and life cycle problems of metallic materials;
- To treat practical applications (energy, automobile, aeronautics, mechanical constructions, civil engineering, ...)

Advanced metal materials play a key role in the design, elaboration and use of manufactured products and structural parts. The acquired skills will enable:

- To understand how a component or metallic piece of structure is made, with what metallic materials
- How the engineers choose and master metallic materials.

Teaching Process (syllabus)

1. Lectures

- Metallurgical concepts (structure, microstructure, defects)
- Introduction to alloys
- Metallic alloys under extreme conditions (low temperature / high temperature, high mechanical strength, large deformations, corrosion resistance, etc.,

2. Industrial case studies: development, characteristics, properties in use

- Precious alloys (Au, Ag, Cu)
- Cryogenic alloys
- Fe, Ni and Fe alloys, Ni, Cr (stainless steels)
- Advanced alloys for nuclear power and energy: zircaloy (cladding of fuel rods in nuclear reactors), Ni base alloys
- Advanced steels for automotive: IFS, DWI, HLE, TRIP, Steel cord
- Alloys for aeronautics and energy: Super alloys, refractory metals, Cermet

3. Industrial case studies: corrosion

Assessment Mode

exams, written tests, oral presentations

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
37.5h	17.5h				**55h**

Proportion of the TU in English:

Innovations in Design and Materials **9MS02** **Semester 9**

Glasses and Simulation of transfers at high temperature

Supervisors: **Mohammed MALKI** **ECTS : 5**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Have a clear image on different families of glasses and glass ceramics
- Simulate industrial processes involving thermal transfer and thermomechanics of materials where radiation is the dominant mode of transfer

Teaching Process (syllabus)

1. Glasses and applications

Glasses background, silicates glasses, elaboration processes of flat glasses (float) and hollow glasses, glass fibers, metallic glasses, glass industry in France and around the world, glass ceramics, vitrification of nuclear wastes, vitrification of industrial wastes, mechanical properties of glasses, bioglasses.

2. Simulation of transfers at high temperature

Basic study of Nastran files and frequently used entries, debugging
Importance of radiation in transport phenomena at high temperature, radiation exchange between several surfaces, solid-liquid transformation, Simulation of some industrial processes involving thermal transfer at high temperature.

Assessment Mode

written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
35h	20h				**55h**

Proportion of the TU in English: ⚐⚐

Innovations in Design and Materials **9MS03** **Semestre 9**

Thematic Scientific Conferences

Supervisors: **Jacques POIRIER** **ECTS: 1**

Learning Outcomes

The confrontation with professionals, working in the field of materials, in terms of knowledge, know-how and life skills is essential to the training of students.
The characteristics on which the engineering profession is based: creativity, curiosity, dynamism, scientific and technical competence, teamwork will be presented during these conferences.
After this cycle of conferences, the student will be able to:

- Better know the engineering professions, in the field of material
- To define their future choices with discernment (internship and future activity)

Teaching Process (syllabus

10 lectures in the field of materials will be presented
For example: metals, alloys, ceramics, cement, composites, glasses, ...
Applications: energy, nuclear, aeronautics, automotive, civil engineering, health, electrical engineering, materials for instrumentation and measurement ...

Assessment Mode

written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
10h					**10h**

Proportion of the TU in English:

Innovations in Design and Materials **9MS04** **Semester 9**

Advanced materials and properties/structures/processes relation

Supervisors: **Domingos DE SOUSA MENESES** **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Choose a suitable composite process for a given application, design and optimize this process to anticipate the induced properties.
- Perform numerical simulations of draping and injection of composites.
- Select a thermal control device
- State a multiphysics problem: identification of partial derivative equations and boundary and initial conditions.
- Simulate coupled multiphysical phenomenon using COMSOL software
- Interpret results and identify limitations

Teaching Process (syllabus)

1. Composite materials and processes

Manufacturing processes of structural composites for industrial applications. Choice of process for a given application. Composite forming and link between formability and mechanical properties of reinforcements. Modelling and numerical simulations of shaping processes using a geometrical approach and a finite element method (CATIA and PAM FORM). Permeability of reinforcements. Modeling and simulation of the injection step of LCM processes (PAM RTM). Induced properties and residual stresses.
Optimization strategies of shaping and injection through industrial case studies.

2. Thermal control

International temperature scale. Contactless temperature measurement. Control and diagnostic.

3. Multiphysics simulation

Heat transfer: heat equation and Fourier's law. Charge transfer: continuity equation and Ohm's law. Electro-thermal coupling: Joule heating. Solid mechanics: stress and strain. Electro-thermo-mechanical coupling: thermal expansion. Mass transfer: Fick's law. Porous media. Effective diffusivity and tortuosity.

Assessment Mode

tests, homework, reports

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
12.5h	27.5h				**40h**

Proportion of the TU in English:

Innovations in Design and Materials **9MS05** **Semester 9**

Ceramics

Supervisors: **Marie-Laure BOUCHETOU** **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Master the processes used to engineer ceramic materials
- Know the main properties of ceramic uses;
- Understand concepts necessary for engineering and forming ceramic materials, their properties and limitations of use;
- Tackle practical applications (energy, automotive and aeronautical engineering, mechanical construction, civil engineering, etc.)
- Know the main methods of characterization of advanced materials

Teaching Process (syllabus)

Ceramics : production and high temperature applications

- Recap of the fundamentals in ceramic
- Ternary phase diagrams
- Methods to produce ceramics, practical case study: silicate ceramics, refractory ceramics, techniques
- High-temperature heat treatment of ceramics. Sintering in ceramics
- Industrial case studies: engineering, characteristics, properties of use. Ceramics for energy, environment application…

Method of characterization of advanced materials

- Microstructure (optical microscope, SEM, TEM)
- Thermal analysis
- Raman spectroscopy
- Infrared spectroscopy
- NMR
- Pore size distribution, XRays tomography, BET

Assessment Mode

written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
32.5h		17.5h			**50h**

Proportion of the TU in English:

Innovations in Design and Materials **9MS06** **Semester 9**

Industrial cases study

Supervisors: **Marie-Laure BOUCHETOU** **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Use the knowledge and analysis methods seen in the training, to deal with concrete industrial cases
- Develop a project and analysis methodology.
- Work independently in a multidisciplinary group.
- Write a project report
- Present the results acquired

Teaching Process (syllabus)

During this teaching unit, students work on a technical project supervised by a scientific tutor (s).

Organization:

The autonomy of the student associated with a project team is the main rule that prevails in this UE.
Weekly meetings are planned to manage the progress of projects.
The project will be the subject of a written report with a summary in English, and an oral presentation.

Scientific content:

The content will focus on real case studies, from our industrial partners, dealing with material issues (metal, refractory, ceramics, glass, composites, etc.) and / or processes.
Problems dealt with in this project framework: Materials and structures characterization, durability and corrosion of materials, establishment of basic knowledge of materials, study of physico-chemical stability, study of aging, relationship between material and structure, relation process / material / properties of use, etc.
The work of each student varies according to the project in which he will be involved, as well as his role within each project team.
This Teaching Unit is part of a process of individualization of the training of students to allow them different learning paths according to their professional and personal projects.

Technical content:

SysML tool to integrate the description of the temporal or event function of the systems

Assessment Mode

Intermediate step by oral defense in English / Triangle of the project in 3mn. 1 final defense before a jury of professionals. Report and final summary note.

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
27.5h	27.5h		16.25h		**50h**

Proportion of the TU in English: ⚐⚐⚐

Innovations in Design and Materials	9EC01	Semester 9

Mechatronic systems

Supervisors: **Emmanuel BEURUAY** **ECTS: 6**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Analyze, model and configure mechatronic systems.
- Study, model and analyze the dynamic, geometric and kinematics behaviors of mechatronic mechanisms.
- Measure the needed signals then model and configure a control law of concrete mechatronic systems.
- Analyze the performance of a system from measurements as well as the limitations of modeling.
- Set a speed control from the industrial documentation

Teaching Process (syllabus)

This teaching unit aims to illustrate the last course in mechatronics context stress environmental sustainability.
This results in the use of components and / or systems, as close as possible of industrial applications, with the desire to model, analyze and control them. Teaching will be mainly taught through practical work on mechatronic systems.

Electromagnetic compatibility (EMC) and the low-frequency disturbances produced. Principle of piezoelectric motors. Solar energy, photovoltaic panels, principles of design and sizing of a photovoltaic system.

Pratical work

DC motors and speed control; automated lifting; photovoltaic system; identification on Brushless motorization; speed variation on asynchronous motorization; electromagnetic disturbances; energy reversibility on continuous and synchronous motorization.
Steward platform (modeling and experimentation); Renault welding gun robot, screwed assembly; parametric optimization of part geometry; Study of a tripod joint; Torsen differential.
Exhaust gas recirculation valve in internal combustion engines; throttle butterfly valve of gasoline engines; catenary train.

Assessment Mode

Several exams, lab reports and homework assignments

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
7.5h	2.5h	55h	7.5h		**65h**

Proportion of the TU in English:

Innovations in Design and Materials 9EC02 Semester 9

Analysis and sizing of mechanical systems

Supervisors: Jean-Marc AUFRERE **ECTS: 5**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Apply hydrostatic laws and study the functioning and design of the hydrostatic power transmission
- Identify the parameters needed to select a pneumatic components for the design of a circuit
- Establish strategies for optimizing and sizing of a cylindrical gear of industrial gearboxes.

Teaching Process (syllabus)

1. Dimensioning component

Material fatigue (Whöler, Goodman, Haigh). Sizing bearing and shaft. Using Kiss-Soft and Kiss-sys software

2. Power transmissions by fluids

Application of the law of hydrostatics; hydraulic components; open and closed circuit; Hydraulic circuit diagram; sizing and performance, electrohydraulic servo valve technology; Criteria for sizing and components choice; Pressure drops (location and effect); Overall assessment and sizing approach of a circuit; functions, characteristics and choice of hydraulic fluids. Specificities of pneumatic power transmission. Production: compressor, dryers, pressure regulator, etc. Uses: order of magnitude of forces, velocities, sequential automation, particular (explosive) atmosphere, "proportional pneumatic"

3. Invited lectures

Technology of electrohydraulic servo valves; static and dynamic characteristics. Equations of motion and stability of servomechanisms. Half-day visit of a servo valves production unit (Zodiac hydraulics).

4. Gear power transmissions

Kinematics; interference; geometrical dimensioning in preliminary design. Operating laws, achievable ratios, energy transit, efficiency and irreversibility of single gear planetary gears. Operating conditions; Teeth degradation; Resistance criteria; Simplified sizing methods; Verification of the load capacity of a component according to ISO6336; Optimizing the design of a component (Specific sliding, scuffing extreme factors, etc.). Dimensioning of a gear in preliminary design, minimum needed data of the technical specifications, iteration process, Using Kiss-Soft and Kiss-sys software

5. Functional tolerancing as a tool increasing energy gain

Functional tolerancing as a tool guaranteeing the performances listed in the bill of specifications (reliability, life span); converting the geometric criteria of the specifications into tolerancing conditions.

6. Lubrication

Different lubrication modes (hydrodynamic, hydrostatic, elastohydrodynamic); permanent, critical and lubricating regimes; lubrication dimensioning and performances

Assessment Mode

written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
36.25h	18.75h		3.75h		**55h**

Proportion of the TU in English: ⚐⚐

Innovations in Design and Materials | 9EC03 | Semester 9

Thematic scientific conferences

Supervisors: Jacques FANTINI | **ECTS: 1**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Understand industrial issues
- Understand how they were treated and resolved
- Know the means implemented

Teaching Process (syllabus)

Manufacturers will expose the problems encountered in their company. They will explain how they were treated and resolved. The experimental and numerical tools implemented will be described and analyzed..

Assessment Mode

written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
10h					10h

Proportion of the TU in English:

Innovations in Design and Materials **9EC04** **Semester 9**

Control strategies and Robotics

Supervisors: **Estelle COURTIAL** **ECTS: 7**

Learning Outcomes

On completing this teaching unit, engineering students will be able to:

- Model and identify a process in the state space;
- Design state feedback control laws (pole placement, decoupling);
- Synthesize state observers (software sensors);
- Implement different control laws (optimal control law, predictive control, visual servoing);
- Use tools and techniques to simulate, plan and control the motion of robotic systems.

Teaching Process (syllabus)

- Modeling processes as state space representations.
- Study of system properties (controllability, observability, stability).
- Design of state feedback control laws (pole placement, decoupling control, linearizing control).
- State observers (soft sensor): Luenberger, Kalman
- Model simplification methods (Shur, Padé)
- Introduction to robotic system modeling
- Advanced control laws: predictive control, optimal control, linear quadratic control (LQC), robustness of a linear quadratic regulator (LQR), visual servoing.
- Identification (nonlinear programming)

Various applications will be studied in class using the following tools: Matlab, Simulink and Control toolbox.

Lab works : Practical applications on mobile robots and manipulated arm.

Assessment Mode

written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
33.75h	35h	11.25h			**80h**

Proportion of the TU in English: ⚐⚐

Innovations in Design and Materials	9EC05	Semester 9

Collaborative Projects

Supervisors: Benoit LE ROUX **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Use the knowledge and analysis methods seen in the training, to deal with concrete industrial cases
- Develop a project and analysis methodology.
- Work independently in a multidisciplinary group.
- Write a project report
- Present the results acquired

Teaching Process (syllabus)

During this teaching unit, students work on a technical project supervised by a scientific tutor (s).

Organization:

The autonomy of the student associated with a project team is the main rule that prevails in this UE.
Weekly meetings are planned to manage the progress of projects.
The project will be the subject of a written report with a summary in English, and an oral presentation.

Scientific content:

Project management and design of mechatronics and robotics systems: project team management, risk analysis, sizing and selection of mechanical components, study of control laws and correctors in servo control, programming of robots, etc.
The work of each student varies according to the project in which he will be involved, as well as his role within each project team.
This teaching Unit is part of a process of individualization of the training of students to allow them different learning paths according to their professional and personal projects.

Technical content:

SysML tool to integrate the description of the temporal or event function of the systems

Assessment Mode :

Intermediate step by oral defense in English / Triangle of the project in 3mn. Final defense before a jury of professionals. Report and final summary note.

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
27.5h	27.5h				**55h**

Proportion of the TU in English: ⚐⚐⚐

Innovations in Design and Materials **9MP01** **Semester 9**

Nonlinear mechanics

Supervisors: **Alain GASSER** **ECTS: 6**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Study the nonlinear aspects of mechanics of structures
- Recognize the type of material nonlinear behavior and choose an associated law
- Identify the parameters of material nonlinear behavior laws
- Use the most common nonlinear behavior laws
- Solve a problem of large displacements (geometrical nonlinearities)
- Use contact processing techniques

Teaching Process (syllabus)

Nonlinear behavior of materials

- Thermodynamical approach for material behavior law building.
- Study of different nonlinear behaviors: plasticity, damage, failure, viscoelasticity, hyperelasticity.
- Identification of the parameters of these nonlinear laws.
- Examples of use of these laws in problems of continuum media mechanics

Contact, geometrical nonlinearities

Analysis and computation of structures with nonlinear behavior (geometrical and contact):

- Origin of nonlinearities
- Mechanics with geometrical nonlinearities
- Taking into account the behavior nonlinearities
- Contact treatment

Finite element method applications

Analysis and calculation (using a finite element software) of structures with nonlinear behavior: material (plasticity, visco-elasticity, hyperelasticity), geometrical and contact non-linearities.
Beams. Rigid bodies. Buckling. Remeshing. Topology optimization.

Assessment Mode

Written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
20h	50h				**70h**

Proportion of the TU in English: ⚐⚐

Innovations in Design and Materials 9MP02 Semester 9

Composites and processes

Supervisors: Jean-Luc DANIEL **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Choose a suitable composite process for a given application, design and optimize this process to anticipate the induced properties.
- Perform numerical simulations of draping and injection of composites.
- Implement advanced characterization techniques in the field of composites materials processes.

Teaching Process (syllabus)

- Manufacturing processes of structural composites for industrial applications.
- Choice of process for a given application.
- Composite forming and link between formability and mechanical properties of reinforcements.
- Modelling and numerical simulations of shaping processes using a geometrical approach and a finite element method (CATIA and PAM FORM).
- Permeability of reinforcements. Modeling and simulation of the injection step of LCM processes (PAM RTM).
- Induced properties and residual stresses.
- Optimization strategies of shaping and injection through examples.
- Approach and rules of design of a composite structure.
- Application to industrial case studies.

Assessment Mode

Several exams, lab reports and homework assignments

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
15h	25h				**40h**

Proportion of the TU in English: 🏳🏳🏳

Innovations in Design and Materials | 9MP03 | Semester 9

Multiphysics couplings

Supervisors: Alain GASSER **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Write properly a multiphysics problem
- Use a commercial finite element code to solve a multiphysics problem
- Analyse and understand the results of multiphysics numerical simulation

Teaching Process (syllabus)

1. Lesson

- Advanced thermomechanics
- Thermo-porormechanic
- Numerical treatment of transport equation, coupling between time and space integration
- Basics of the thermodynamics for irreversible processes

2. Methods and numerical tools (FEM codes : Abaqus, Comsol)

- Heat and elctrical charge transport
- Thermomechanic : transient and steady-state
- Thermo-electro-mechanic coupling
- Thermoporoelasticity : transient effects.

Assessment Mode

Written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
12.5h		27.5h			**40h**

Proportion of the TU in English: ⚐⚐

Innovations in Design and Materials	9MP04	Semester 9

Thematic scientific conferences

Supervisors: **Alain GASSER** **ECTS: 1**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Understand industrial problematics
- Understand how they were treated and solved
- Know the used means

Teaching Process (syllabus)

Engineers from industrial partners will come to present problematics that their company has met. They will explain how they were treated and solved. The used experimental and numerical tools will be described and analyzed.

Assessment Mode

Written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
10h					**10h**

Proportion of the TU in English: ⚐⚐

Innovations in Design and Materials	9MP05	Semester 9

Advanced simulations

Supervisors: Jean-Luc DANIEL — **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- • To know the different hypotheses constituting models of beams, plates and shells.
- • Know the main finite elements based on these models.
- • Define the framework for their use.
- • Know how to carry out EF calculations in the field of simulation of formatting processes.

Teaching Process (syllabus)

- Study of simplified models of beams, plates and shells.
- Case of thin elastic shells.
- Finished elements of plates and shells.
- Case of finite transformations.
- Simulations of formatting and crash processes.

Assessment Mode

Written test

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
20h	30h				**50h**

Proportion of the TU in English:

Innovations in Design and Materials **9MP06** **Semester 9**

Industrial applications

Supervisors: **Jean-Luc DANIEL** **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Use the knowledge and analysis methods seen in the training, to deal with concrete industrial cases
- Develop a project and analysis methodology.
- Work independently in a multidisciplinary group.
- Write a project report
- Present the results acquired

Teaching Process (syllabus)

During this teaching unit, students work on a technical project supervised by a scientific tutor (s).

Organization:

The autonomy of the student associated with a project team is the main rule that prevails in this UE.
Weekly meetings are planned to manage the progress of projects.
The project will be the subject of a written report with a summary in English, and an oral presentation.

Scientific content:

The content will focus on real case studies, from our industrial partners, focusing on material, structure and process simulation issues.
Problems dealt with in this project framework: shaping of metal parts or composites, modeling and simulation of multi-physical behaviors, (thermal, mechanical, chemical, hygrometric, etc.), impact simulation, multi-scale modeling and simulation, design and calculation of composite parts, topological optimization, modeling of living materials, etc.
The work of each student varies according to the project in which he will be involved, as well as his role within each project team.This Teaching Unit is part of a process of individualization of the training of students to allow them different learning paths according to their professional and personal projects.

Technical content:

SysML tool to integrate the description of the temporal or event function of the systems. (idem pour les logiciels métiers)

Assessment Mode :

Intermediate step by oral defense in English / Triangle of the project in 3mn. Final defense before a jury of professionals. Report and final summary note.

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
27.5h	27.5h				**55h**

Proportion of the TU in English: 🏳🏳🏳

Innovations in Design and Materials	AIC01	Semester 10

Project

Supervisors: **Jacques FANTINI** **ECTS: 10**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Write a product specification based on a requirements analysis
- Establish the functional and technological specifications of a project
- Establish milestones and provide project deliverables
- Manage a project

Teaching Process (syllabus)

Organization:

During this teaching unit, students work on a technical project supervised by a scientific tutor. The project is "full time" from early January to mid-March. It ends with a written activity report, a poster in English and an oral exam

Scientific content:

- The subjects of projects proposed to the student engineers are very varied. We can make a feasibility study of a new concept, design a process for a dedicated application, improve a theoretical knowledge, realize an industrial study, etc ...
- In any case, the student engineer must show his ability to manage a project, to take initiatives, to be able to share tasks (working in pairs), to carry out a technical study in a given time.

Assessment Mode

Written activity report, oral defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
				170h	**170h**

Proportion of the TU in English: ⚐⚐⚐

Technologies for Energy, Aerospace Engineering and Motorization (TEAM)

Course Unit Code	Course Unit Title	Total Hours without ind. work	ECTS Credits
Fall Semester (September – December)			
9TE01	Professional Lectures – *Conférences métier*	20	3
3 courses to choose below			
9TE02	Turbulence and Advanced CFD – *Turbulence et CFD avancée*	70	7
9TE03	Combustion and Applications – Combustion et applications	70	7
9TE04	Gas Dynamics – *Dynamique des gaz*	70	7
9TE05	Engines – *Moteurs*	70	7
9TE06	Engine and Hybrid Vehicle Control – *Contrôle moteur et véhicule hybride*	70	7
9TE07	Building Energy – *Energie des bâtiments*	70	7
9TE08	Energetic Systems – *Systèmes énergétiques*	70	7
9TE09	Aeroacoustics and Elasticity – *Aéroacoustique et aéroélasticité*	70	7
Spring Semester (January – March)			
ATE01	Project – *Projet d'entreprise*	170	10

Technologies for Energy, Aerospace Engineering and Motorization **9TE02** **Semester 9**

Professional lectures

Supervisor: **Ivan FEDIOUN** **ECTS: 3**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- To have a more precise vision of the different professions to which TEAM can lead
- Better know the industrial applications of the academic courses given during the training

Teaching Process (syllabus)

8 lectures of 2h30 given by professionals experts in their fields of competence

Program for 2017-2018 :

Lecturer	Company	Subject
DUBOIS Thomas	Total	Energy mix, renewable energy
KETFI-CHERIF Ahmed	Renault	Hybrid and Electric Powertrain control
SLANEY David	GRDF	Energy systems
MATHEDARRE Christophe	Safran Aircraft Engines	Thermal management
MORSILI Salah-Eddine	EDF	Energetics
BOQUEL Pierre	ASN	Nuclear safety - Radioprotection
BRULEFERT Frédéric	LORIAS Lab'O	Aeronautics, military aviation
BLOT Yves	Safran Aircraft Engines	Safety/aeronautical regulations

Assessment Mode

Compulsory attendance

Workload

Lectures	Classes	Labs	Individual work	Project work	STUDENT WORKLOAD
20h					20h

Proportion of the TU in English:

Technologies for Energy, Aerospace Engineering and Motorization **9TE02** **Semester 9**

Turbulence and Advanced CFD

Supervisor: **Ivan FEDIOUN** **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Describe, understand and analyze the physical phenomena occurring in turbulent flows;
- Use tools to process and analyze experimental and numerical results;
- Choose the correct level of description/modeling for digital simulation (MILES, LES, DES, RANS) depending on needs and available resources;
- Use the CFD ANSYS Fluent® software for RANS simulation in turbulent flows.

Teaching Process (syllabus)

1. Physical description and statistical analysis of turbulence

- Statistical tools: random variables, statistical moments and 1 or 2-point correlations, stochastic averaging, general theorems
- Physics of turbulence: Eulerian scales in space and time, Kolomogrov scales, Taylor's hypothesis, homogeneous and isotropic turbulence, spectra, double-correlation dynamics, inertial law
- Experimental approach : practical demonstration of measurement techniques in non-reactive flow (hot-wire, LDV, PIV)
- Signal and image processing: time and space averages, Fourier transform, time and space correlations, power of spectral densities. Implementation: LVD signal processing, hot-wire

2. Operational modeling: 1-point closures (RANS)

- Recap and complements: Reynolds' formalism, statistical equations in incompressible flow, closure issues
- RANS formalism in compressible flow: Favre averaging, Morkovin hypothesis
- Newtonian closure: 1-equation (Spalart-Allmaras) and 2-equation (k-ε, k-ω,…) models, wall laws

3. Large Eddy Simulation

- Explicit subgrid filtering and modeling: physical and spectral space, generalized central moments, eddy viscosity models (Smagorinsky, Structure-Function model), scale similarity model (Bardina), Germano identity, dynamic models (Germano-Lilly)
- Implicit large-scale simulation: implicit filtering of a digital scheme, transfer function, dissipative and dispersive schemes, applications

4. CFD applications with ANSYS Fluent® 15.0

5. Conferences given by invited lecturers

Assessment Mode

2 short written tests, homework assignment, lab reports in CDF and experimental lab reports

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
5h	25h	30h	20h	10h	**70h**

Proportion of the TU in English: 🏳🏳🏳

Technologies for Energy, Aerospace Engineering and Motorization **9TE03** **Semester 9**

Combustion and Applications

Supervisor: **Fabien HALTER** **ECTS : 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Acquire the requisite knowledge to describe, understand and analyze laminar and turbulent combustion phenomena coming into play in industrial applications;
- Know the basic mechanisms determining the formation and reduction of pollutant emissions;
- Identify parameters influencing heat release and the formation of the main pollutants (soot, NOx) for applications such as internal combustion engines, thermal power plants (coal, gas, biofuels) and turbine engines. Know how to vary parameters to optimize the working of the energy system;
- Use CFD software to simulate a complex system;
- Acquire an overview of the tools allowing characterizing a reactive or non-reactive turbulent flow.

Teaching Process (syllabus)

1. Theory

- Combustion chemistry (thermodynamics applied to chemistry, chemical kinetics)
- Self-ignition (theory, measurement methods, examples of detailed modeling)
- Premixed flames (flammability limit, flame stabilization, extinction parameters, propagation velocity, flame thickness, …); Diffusion flames
- Combustion high-energy materials and explosives
- Formation of pollutants and post-processing systems
- Flame/turbulence interactions
- Models of turbulent combustion for premixed and diffusion flames
- Illustration of the phenomena of combustion and pollutant formation with recent technologies
- Introduction to tools allowing to characterize a reactive or non-reactive turbulent eddy flow (lab)
- Image processing (digital tool Matlab)

2. Practice

Use of CHEMKIN software. Application of notions tackled through 3D calculation codes (FLUENT)

3. Autonomous supervised project

Students will work by group on a project dedicated to the description and the understanding of an accidental combustion phenomenon. A guided project devoted to the characterization of acoustically perturbed flames using post-processing tools will be proposed.

Four conferences given by industrial stakeholders and researchers will be planned on different topics.

Assessment Mode

At least 3 written tests or exams. 3 presentations in group.

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
30h	10h	30h	3.75h		**70h**

Proportion of the TU in English:

Technologies for Energy, Aerospace Engineering and Motorization **9TE04** **Semester 9**

Gas Dynamics

Supervisor: **Azeddine KOURTA** **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Acquire the knowledge require to calculate, analyze and characterize the physical phenomena present in flows at speeds ranging from high subsonic to hypersonic;
- Master digital tools to predict these flows and understand the role of the mathematical properties of Euler's equations (hyperbolicity, characteristics) in numerical shock-capture schemes (FVS, FDS). Review of the main schemes. Initiation into FORTRAN programming.

Teaching Process (syllabus)

1. Dynamics of high speed flows

- Recap of the 4th year course on thermodynamics, the Euler system, normal shocks
- 1D unsteady flows: characteristics, Riemann invariants, shock tube
- 2D steady flows: oblique shocks, interaction of shocks, Mach disc. Expansion fan, Prandtl-Meyer relation, linearized theory, characteristics, Cauchy problem
- 'Cold' hypersonic airflows: entropy layer, viscous interaction, similarity

2. Numerical methods to solve Euler's equations

- Scalar hyperbolic conservation equations: characteristics, Riemann problem. Weak solutions and Rankine-Hugoniot condition. Entropy solutions
- Recap on Euler 1D system: conservative, primitives and characteristic variables, transformation matrices, Riemann invariants
- Conservative schemes, first-order 'upwind' finite-volume schemes based on flux splitting (FVS) and approximate Riemann solvers (FDS)
- Second-order extension: MUSCL approach, TVD schemes and flow limiters

3. Machine applications with FORTRAN language

- Linear convection: programming, management of boundary conditions
- Burgers' equation: Riemann problem with compressive or expansive initial conditions
- Programming Lax-Friedrichs and CIR schemes with a constant time-step
- Application to the Sod shock tube problem with fixed boundary conditions. Management of boundary conditions: free non-reflective output, reflective closed boundaries, mixed conditions
- Programming the Roe scheme with Harten's entropy fix, adaptive time-step with constant CFL and ordinary boundary conditions

4. Autonomous supervised project

Assessment Mode

3 short written tests, exams, homework assignments

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
25h	25h	20h	12.5h		**70h**

Proportion of the TU in English: ⚐⚐⚐

Technologies for Energy, Aerospace Engineering and Motorization | **9TE05** | **Semester 9**

Engines

Supervisor: **Pascal HIGELIN** | **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Understand the physical and chemical processes taking place during combustion and during fuel injection in internal combustion engines. Use modeling to understand the reaction of a given engine to a change in one of its parameters;
- Construct a model of an internal combustion engine. Optimize the dimensioning and tuning of an engine under various constraints: performance, power, and pollutant emissions, using an engine model.

Teaching Process (syllabus)

- Combustion: thermochemistry and kinetics applied to combustion. Self-ignition. Premixed flames, flammability limit, flame stabilization, extinction parameters and turbulent combustion. Diffusion flames. Two-phase combustion. Internal engine aerodynamics. Notions of preparation of the mixture, definition of the requirements for spark ignition and for self-ignition, combustion initiation and propagation (definition of the basic combustion speeds), pollutant formation. Definition of user drivability requirements in terms of fundamental data
- Thermodynamic models: classification into air models, single-zone models, two-zone models, multizone models. Models of combustion chamber wall losses. Limits of validity.
- Combustion models: semi-empirical model of Vibé, application to a controlled ignition engine. Extension of the model to compression ignition engines. Models for controlled ignition engines. Models for compression ignition engines (jet, vaporization, self-ignition delay, premixed phase and diffusion phase combustion models)
- Fuel injection models: filling/emptying model and 1D intake/exhaust gas dynamics model. Boundary conditions: open, closed, and partly open intake manifold, junctions. Heat losses and losses due to wall friction. Reconstruction of the filling curves
- Turbocharging: static and dynamic models of the turbocharger. Turbocharger performance and speed maps. Turbine/compressor adaptation. Pumping limit. Dynamics of the turbocharger, response time
- Specific tools: Matlab/Simulink, GTpower, Chemkin. Assembling engine models from component libraries, using the detailed models analyzed in this teaching unit

Assessment Mode

3 reports

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
22.5h	42.5h			5h	**70h**

Proportion of the TU in English: ⚐⚐⚐

Technologies for Energy, Aerospace Engineering and Motorization — **9TE06** — **Semester 9**

Engine and Hybrid Vehicle Control

Supervisor: **Guillaume COLIN** — **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Master engine control systems, control strategies and the associated control devices;
- Implement control strategies for internal combustion engines;
- Apply the knowledge acquired in class to the tuning and control of internal combustion engines on a test bench, an actuator bench or via simulation;
- Perform energy balance on a hybrid vehicle and generate an energy management strategy.

Teaching Process (syllabus)

1. Theory

- History of engine control: carburetor, mechanical injection
- State of the art: sensors, actuators, hardware and software implementation of the controller, strategies
- Spark ignition engine control: basic strategies (fuel enrichment, ignition advance), pollution control (fuel enrichment adjustment, catalyst, light-off, EGR), detecting knock, anti-knock strategies, idle, start, cold start, drivability
- Diesel engine control: basic strategies (quantity of injected fuel, smoke limit), multiple injection, homogeneous charge engines, idle, start, cold start, drivability
- Development methods
- Embedded networks
- Embedded models: intake manifold dynamics, turbochargers, fuel, friction
- Automatic control: PID control and advanced control
- Control based on physical or heuristic models, torque control
- Hybrid vehicles: definitions, issues, energy management (heuristic, optimal, Equivalent Consumption Minimization Strategy)

2. Practice

- Tuning an internal combustion engine; Engine control; Energy management of an hybrid vehicle
- Labs will be conducted on a real engine test bench, on an actuator bench system, and on a roller bench. 2 labs will be conducted at John Deere in Saran for a limited number of students.

This teaching unit also aims at raising awareness among engineering students regarding engine control and its tuning (engine mapping, PID control, advanced control).

3. Mini-project

Project on Engine and Hybrid Vehicle Control, e.g. in 2017/2018 the pre-sizing of the technical elements of an HEV and designing the energy management with the softwares Amesim and Simulink.

Assessment Mode

Lab reports, oral defense, homework assignments, mini-project report and defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
20h		50h	30h		**70h**

Proportion of the TU in English: ⚐⚐⚐

Technologies for Energy, Aerospace Engineering and Motorization — **9TE07** — **Semester 9**

Building Energy

Supervisor: Jean-Michel FAVIÉ — **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Identify professional elements in different technical and human fields related to "chargé d'affaires" engineers specialized in building and sustainable energies;
- Master different standards, classic and sustainable production means and production modes coordination. Suggest economical and innovative solutions respectful of the environment.

Teaching Process (syllabus)

1. Environmental standards, regulations and requirements

Thermal control, very high quality sustainable architecture (THQE), para-public labels, Agenda XXI, project conduct with decision-makers (town halls, promoters, private companies...). Environmental footprint, embedded energy et LCA (Life Cycle Analysis)

2. Thermal auditing and diagnostic

Environmental audit, EPD (Energy Performance Diagnostic) and carbon balance. Needs identification (AMO) and implementation of eco-responsible improvements. Simple assessment models for suggested solutions

3. Passive energetics

Conventional and bio-sourced materials. Architecture, header captors, solar walls, etc.

4. Digital models

Homogenization theory, transitory regulation models (DF, EF, integrators)

Predictive approach and use plan management. Release, production and consumption grouping to achieve energy management

5. Renewable energies

How to invert primary and secondary production sources. Solar thermal energy, wind power, shallow or great depth geothermal energy. Collaboration between different production modes as a function of needs

6. Heat exchangers

Heat pumps, fin heat exchangers. Wood burners and forests sustainable management

Assessment Mode

1 project conduct, 1 homework assignment: modeling and energies integration, written tests

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
45h	18.75h	6.25h	21.25		**70h**

Proportion of the TU in English: ⚐⚐

Technologies for Energy, Aerospace Engineering and Motorization — 9TE08 — Semester 9

Energetic Systems

Supervisor: Camille HESPEL — **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Dimension an energy production system (combined cycle, steam power plants and boilers);
- Apply notions of security and nuclear safety.

Teaching Process (syllabus)

Energy production on the industrial scale

- Nuclear power plants (principle, primary and secondary cycles, safety)
- Thermal power plants (functioning of a facility)
- District heating systems

The different components in energy production

- Steam generators
- Steam turbines
- Boilers (water circulation, furnace design)
- Exchangers

Advanced thermodynamics

- Study of water/steam cycles
- Enthalpy and Mollier diagrams
- Study of the combine cycle gas (general functioning, principles and applications)

System optimization

- Main controls (power, temperature, level)
- Cogeneration

Geopolitics of energy

- National, European and international regulation
- Alternative energies
- Short and long-term issues
- Life cycle assessment

Assessment Mode

3 exams and a written report

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
43.75h	20h	6.25h	30h		**70h**

Proportion of the TU in English:

Technologies for Energy, Aerospace Engineering and Motorization | **9TE09** | **Semester 9**

Aeroacoustics and Elasticity

Supervisor: **Philippe DEVINANT** **ECTS: 7**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- understand and describe the main physical phenomena associated with aeroacoustic (aerodynamically generated noise) and aeroelastic (coupling between aerodynamics and elastic deformations) aspects and their effects, in particular those associated with the unsteadiness of fluid flows
- carry out some simple modeling.

Teaching Process (syllabus)

1. Aeroacoustics

General notions about aerodynamic noise, fields of application, sound propagation in flows in homogeneous media, calculation of the radiated noise, noise sources, interaction between flows and acoustics. Concrete examples of noise nuisances. Unsteady wave motion. Representative parameters of local noise motion. Intensity, noise level, noise sources. Propagation equation with and without flow. Theory to calculate aerodynamic noise (Lighthill's analogy)

2. Aeroelasticity

On the basis of the classic tools for steady and unsteady aerodynamics and for the mechanics of deformable solids, describe, analyze and model the main characteristics of the steady and dynamic behavior of deformable objects (airfoils, wings, rotors, etc.) subjected to the interaction between elastic, inertial and aerodynamic forces, which may lead to stationary aeroelastic divergence or unsteady flutter. Introduction to fluid-structure coupling. Recap on elasticity - strength of materials and aerodynamics. Steady aeroelasticity: formulation of the problem, analysis of the divergence of a large aspect ratio wing and of the control surface reversal phenomena. Dynamic aeroelasticity: formulation of the problem; difference between the different modes of aeroelastic coupling (resonance, flutter). Flutter in steady aerodynamics and application to a wing much more flexible in flexion than in torsion: aeroelastic stability and dynamic response using the model cross-section. Unsteady aerodynamic modeling of an airfoil and its effects on the previous results

Assessment Mode

Several written tests, exams and homework assignments in the course of the TU

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
37.5h	32.5h		12.5h		**70h**

Proportion of the TU in English: ⚐⚐⚐

Technologies for Energy, Aerospace Engineering and Motorization	ATE01	Semester 10

Project

Supervisor: **Pierre BREQUIGNY** **ECTS: 10**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Conduct a study to solve an industrial or research issue using an engineering approach;
- Develop and consolidate disciplinary skills acquired during the three-year training;
- Set a bill of specifications and schedule tasks;
- Perform regular follow-up with the actors of the project, plan follow-up meetings;
- Work autonomously;
- Synthesize the progress made and present them in a written report and oral presentation.

Teaching Process (syllabus)

- Project and format selection (solo, duo or group work)
- Establishment of contact with the limited partner of the study (company or laboratory)
- Writing of the bill of specifications submitted to the limited partner for approval
- Task scheduling and follow-up meetings
- Identification of the tools and resources necessary to the project conduct
- Risk analysis and fallback solutions
- Technical realization of the study
- Update of the project follow-up and implementation of fallback solutions if required
- Delivery of a synthesis report
- Oral presentation of the results of the study

Assessment Mode

Report and oral defense

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
				170h	**170h**

Proportion of the TU in English: ⚐⚐⚐

All trainings – Classics teaching units

Course Unit Code	Course Unit Title	Total Hours without ind. work	ECTS Credits
Fall Semester (September – December)			
9Hx01*	Operationnal Management – *Management opérationnel*	36.25	4
9Hx03*	Intercultural communication - start up project	10	2

* x = C for Civil and Geo-environmental Engineering training
P for Engineering Physics and Embedded Systems training
M for Innovations in Design and Materials training
T for Technologies for Energy, Aerospace Engineering and Motorization training

Humanities **9Hx01** **Semester 9**

Operational Management

Supervisor: **Jean-Jacques YVERNAULT** **ECTS: 4**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Apply methods of group leadership and negotiation;
- Understand the factors that drive motivation;
- Use quality control tools in problem-solving;
- Determine the occupational hazards of a workstation and analyze the company's safety policy;
- Include work ethic to their trade;
- Understand the different steps of industrial patent design, writing and registration;
- Perform efficient industrial patent search and reading;
- Optimize their CV and interview skills so as to obtain an interesting internship.

Teaching Process (syllabus)

1. Operational management

Giving a debriefing of management situations encountered during the 4th year work placement; creating management cases (Personal Evolution and Employability of the UNIT project); understanding the role and responsibilities of an engineer in company management; handling complicated cases and conflicts; conducting interviews and run meetings; negotiating purchases and sales methodically.

2. Quality and safety management

Methodical problem-solving; using tools proper to lean management approach ; including work ethic in management; preventing and tackling psychosocial risks; analyzing and diagnosing occupational hazards in order to control them.

3. Patent of invention and industrial property

Understanding the existing links between innovation and industrial property; knowing patent registration criteria; being able to localize the different sections of a patent of invention when reading it; knowing how to make a patent database search to find relevant information.

4. Recruitment

Writing a CV and cover letters that include the work experience gained in the 4th-year placement; planning a meeting for the next work placement; introducing and making oneself an attractive work candidate in an assessment interview role-play.

Assessment Mode

Written report on solving a management case (in teams), written report on a work ethic case. Mooc certificate on industrial property and invention patent, oral exam (recruitment simulation)

Workload

Lectures	Classes	Labs	Individual work	Project work	STUDENT WORKLOAD
	32.5h	3.75h			36.25h

Proportion of the TU in English: ⚐⚐

Humanities **9Hx03** **Semester 9**

Intercultural Communication – Start up project

Supervisor: **Adèle BRIERLEY-LOUETTE** **ECTS: 2**

Learning Outcomes

On completing this teaching unit engineering students will be able to:

- Get organized in a team to design and create a virtual « Start-Up » company which will be located in a foreign country
- Do the research and the necessary steps to the creation of this virtual company abroad
- Introduce and defend in team the research and the project of “Start-up” in front of an exam board.

Teaching Process (syllabus)

- Research and creation of a virtual company to set up abroad
- Autonomous team work
- Regular follow-up meetings
- Debates and oral presentations

Assessment Mode

1 written exam, 1 timed oral presentation, 1 professional interview, intercultural fair participation

Workload

Lectures	Classes	Labs	Individual work	Project work	**STUDENT WORKLOAD**
		10h	12.5h		**10h**

Proportion of the TU in English: ⚐⚐⚐

Personal Projects

Available during the Fall and the Spring Semesters, students can work on a project with a Polytech Orléans teacher in English.

The subject of the Project must be defined in advance on a Learning Agreement, between the student and his academic coordinators from his home institution and his host institution.

Projects can be done in the following departments:

- Civil and Geo-environmental Engineering,
- Engineering Physics and Embedded Systems,
- Innovations in Design and Materials,
- Technologies for Energy, Aerospace Engineering and Motorization,
- Industrial Engineering applied to Cosmetics, Pharmacy and food-processing Industry.

Course Unit Code	Course Unit Title	Total Hours without ind. work	ECTS Credits
UP05	Project for exchange student – *Projet pour étudiant en échange*	~ 2 weeks	5
UP10	Project for exchange student – *Projet pour étudiant en échange*	~ 1 month	10
UP15	Project for exchange student – *Projet pour étudiant en échange*	~ 6 weeks	15
UP20	Project for exchange student – *Projet pour étudiant en échange*	~ 2 months	20
UP30	Project for exchange student – *Projet pour étudiant en échange*	> 3 months	30

French Courses

International students can attend French courses at the French Institute of the University of Orléans. These courses take place on late afternoons, during the week, and cost **50€/semester**.

At the beginning of each semester, students must take an exam to determine their level in French.

There are **4 different levels**: Beginners, Intermediate, Advanced and Superior.

Each course is equivalent to 2 ECTS credits.

Different courses:

Fall semester		Spring semester	
Courses	Code	Courses	Code
Beginner		Beginner	
Written	FA1O1FRE	Written	FA1O2FRE
Oral	FA1O1FRO	Oral	FA1O2FRO
Intermediate		Intermediate	
Written	FA2O1FRE	Written	FA2O2FRE
Oral	FA2O1FRO	Oral	FA2O2FRO
Advanced		Advanced	
Written	FB1O1FRE	Written	FB1O2FRE
Oral	FB1O1FRO	Oral	FB1O2FRO
Grammar	FB1O1GRA	Grammar	FB1O2GRA
University methodology	FB1O1FOU	University methodology	FB1O2FOU
Superior		Superior	
Written	FB2O1FRE	Written	FB2O2FRE
Oral	FB2O1FRO	Oral	FB2O2FRO
Grammar	FB2O1GRA	Grammar	FB2O2GRA
University methodology	FB2O1FOU	University methodology	FB2O2FOU

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