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POLYTECH©
ORLÉANS
Ecole d’ingénieurs de l’université d’Orléans

COURSE SYLLABUS

Polytech Orléans

Course offer in English

2024-2025

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Foreword

This booklet gathers the courses that are taught in English at Polytech Orleans.

In the first part, *“teaching packages”* corresponding to different majors in Engineering are proposed. The student can choose one of them: they include all the courses for one semester at Polytech Orleans for each major. They are fully taught in English. By selecting a “teaching package”, the student makes sure that there will not be any class schedule overlap. The total number of credits in “teaching packages” is about 30 ECTS.

In the second part of the booklet, a list of courses that are fully or partially taught in English are also listed with their corresponding number of ECTS.

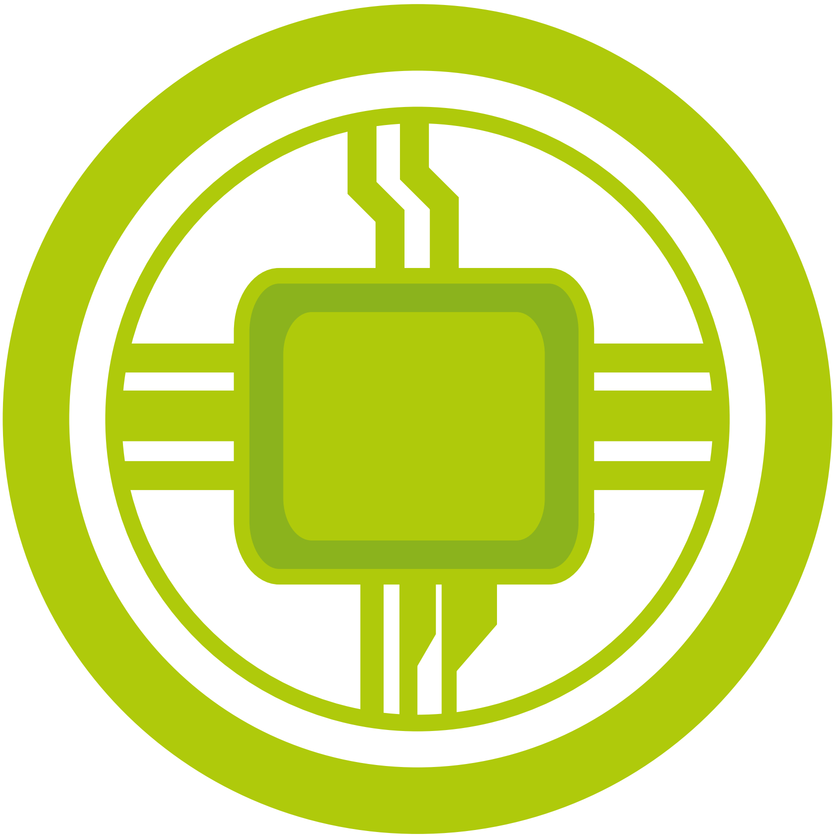
Note that it is also possible attend courses in French for foreigners to complete your learning agreement.

	Extra courses at the French Institute (65€/ semester)	**ECTS**
1	Written French	**2**
2	Oral French	**2**

Content

Packages of courses entirely taught in English

Engineering Physics and Embedded Systems (GPSE)



PLASMA ENGINEERING PACKAGE

5th year- Master 2				
Fall Semester (September – December)		Course Unit code	Total Hours	ECTS
1	Plasma Engineering Courses	9GP08	**70h**	**7**
2	Practical applied learning	9GP10	**40h**	**5**
3	Engineering Project Phase 1	9GP07	***100h***	**9**
4	Project with Gremi Lab for foreign students	POLUP10		**10**
Total			***260h***	**31**

Softskills available with this package :

5	Intercultural communication	9HP02	**22h30**	**2**
6	Intercultural communication start up project	9HP03	**10h**	**2**

1) PLASMA ENGINEERING COURSES (70H)

Unit	Courses	Hours
Plasma general properties (25h)	Plasma general properties (neutrality, Debye Length, plasma frequency…)	2 :30
	Plasma dynamics (basic motions in E and B fields)	2 :30
	Bolzmann’s equation	2 :30
	Distribution functions and exercises	5 :00
	Particle, Momentum and energy conservation	2 :30
	Atomic collisions – Elastic scattering – Inelastic scattering	5:00
	Waves in a plasma	2 :30
	Tests	2 :30
Introduction to high pressure plasma (15h)	Equilibrium Vs. non Equilibrium	2:30
	Streamers	2:30
	High pressure discharges	5:00
	Medical and applications	2:30
	Tests	2:30
Low pressure plasmas (30h)	DC discharge	2:30
	Sheath	2:30
	Diffusion	2:30
	Power balance	1:15
	RF sheaths	1:15
	Capacitively coupled plasmas	2:30
	Inductively coupled plasma	2:30
	Matching networks	3:45
	Langmuir probes	2 :30
	Global model	5 :00
	Tests	3 :45

2) PRACTICAL APPLIED LEARNING (40 HOURS)

These projects are dedicated to teaching systems, processes and diagnostics in plasma engineering. They are proposed to better understand **theoretical concepts** of plasma dedicated courses. Each group of 2 students will work on 3 **projects**. Each project will last **3 days** (6h15 of experimental work per day). They will be supervised by **professors** and a **research engineer**. One of the 3 projects will be organized in the **clean room facility**.

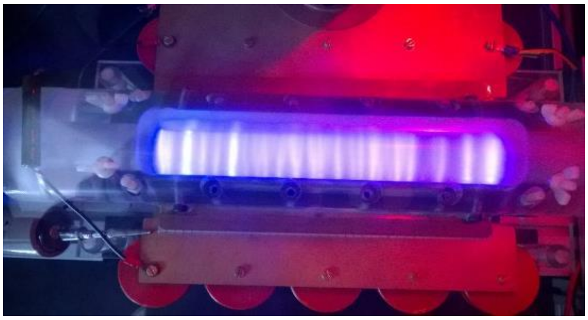
Competences for each project:

	N_2 Laser	DC Disch	RF/TCP	LIF	Jet	MHCD	Etching	PVD	PECVD
LAS	✓			✓					
LP PLAS	✓	✓	✓	✓			✓	✓	✓
HP PLAS					✓	✓			
VACUUM			✓			✓	✓	✓	✓
OPT	✓		✓	✓		✓			
SPECTRO	✓	✓	✓	✓	✓	✓			
ELEC	✓	✓	✓	✓	✓	✓			
MAT							✓	✓	✓
Faraday/Langmuir							CLEAN ROOM		

LAS : Laser
LP PLAS : Low Pressure Plasma
HP PLAS : High Pressure Plasma
SPECTRO : spectroscopy diagnostics (emission, absorption, …)
ELEC : electrical diagnostics (oscillo, probes, electrical measurements, …)
MAT : materials characterisation

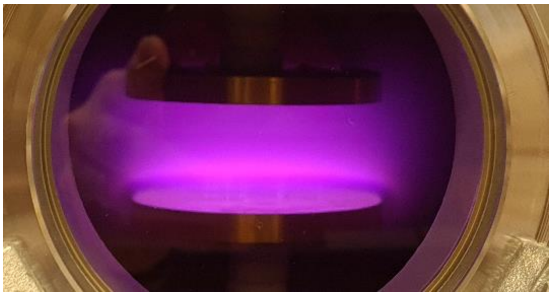
1. *N_2 LASER* – UV pulsed laser : electrical and optical optimisation

The objective of this project is to build a UV laser with a system looking like those used for excimer pulsed lasers. For safety reasons, the discharge is carried out in nitrogen rather than in a halogen gas. This UV laser will serve to pump a dye laser.
- Follow the subject, answer the questions.
- Vary the number of knob capacitors to see its effect on the laser performances and the voltage waveforms. Get information on excimer lasers.



Skills: use correctly an oscilloscope, fluid manipulation, use a high voltage powersupply, make a pulsed power system, characterize the emission by photodiode and by spectroscopy.

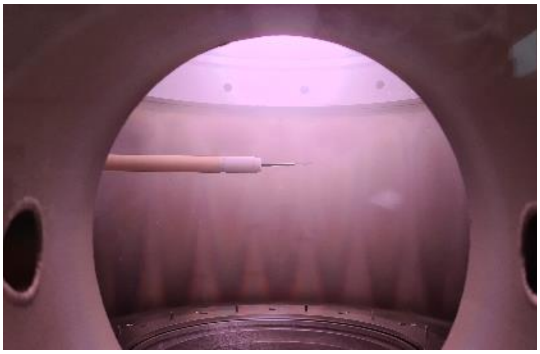
2. *DC DISCH* – Breakdown in a gas. DC discharges for lighting applications



The objective of this project is to analyse a DC discharge at low pressure (ignition and operation regimes). Different gases will be studied (Ar, N_2 and He).
Study of the breakdown in different gases (Paschen law,…).
Analyse $V_{breakdown}$ versus the product pressure times electrode distance. Fit with the theoretical curve. Find the coefficients and compare with theoretical values. Make a statistic on each point of the breakdown curve. Plot V-I curves – Identify the different regimes for each gas.

Skills: generate a DC discharge, plasma diagnostic, electrical circuit for V-I acquisition, breakdown in gases, discharge regimes.

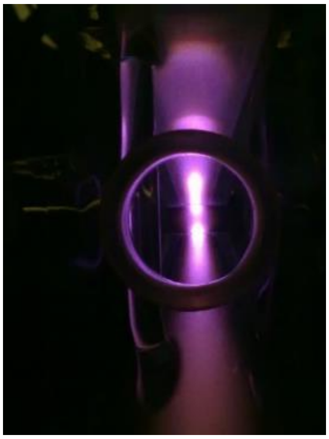
3. *RF* – Radio frequency discharges.



The objective is to analyse and use an RF discharge, which is usually used in microelectronics processing. The transition from capacitive (E) to inductive (H) will be studied. A spectroscopic study will be carried out in a mixture of Ar and H_2. A Langmuir probe will be installed to analyze the plasma in different conditions of operation. An RF probe will be used to determine the plasma impedance.

Skills: generate an RF discharge, use a RF power supply, matching networks, spectroscopy (OES), vacuum technology, oscilloscope, Hydrogen dissociation.

4. *LIF* – Laser Induced Fluorescence

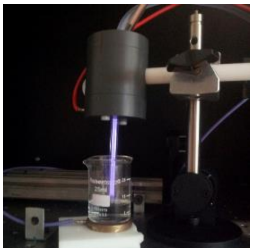


The objective of this project is to evidence the laser induced fluorescence in argon plasma. Several transitions will be studied. The evolution of the metastable density will be evaluated versus pressure and current.
Equipment characterization: Photomultiplier (PM), laser, oscilloscope, OPO crystal, …
For the PM, study the emission of a line versus bias voltage of the PM. Check the saturation threshold of the PM.
Study the LIF at 800.6 nm, and then at other wavelengths.
Write the balance equations. Compare the deexcitation characteristic time and compare it to the theoretical value given by the balance equations. Comment the obtained results. Try to plot the relative metastable density versus pressure and discharge current.

Skills: Use of a Nd :YAG laser, doubled in frequency, OPO crystal, DC high voltage, PM signal measurement

5. *Jet* – Plasma jet

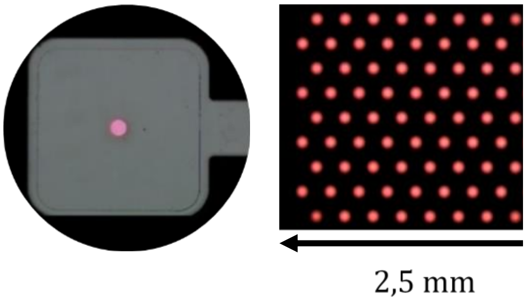
The objective is to characterize a plasma jet usually used for medical applications. You will use a high frequency power supply (10kHz) producing DBD type discharges travelling along a dielectric tube at high velocity. The jet characterization will be carried out by electrical and optical measurements. Experiments on surface treatment will be carried out as well.



Skills: Plasma at atmospheric pressure, electrical and optical characterization, treatment process.

6. *MHCD* – MicroHollow Cathode Discharges

The objective is to study and characterize microdischarges operating in DC. The typical dimension of the discharge is 100 µm. The microdevices are prepared in the clean room. You will use a high speed camera, a spectrometer, an oscilloscope and probes to characterize the different regimes of the microdischarges operating in atmospheric pressure of Ar, He and N_2. The discharge breakdown and the selfpulsing regime will be investigated. You will also try to light up an array of microdischarges.



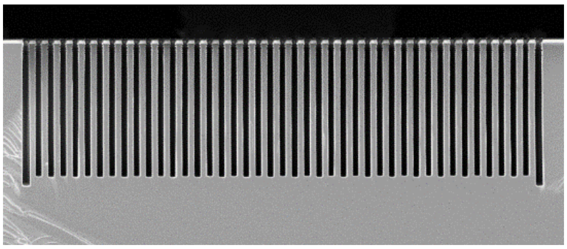
Skills: Plasma at atmospheric pressure, electrical and optical characterization, electrical circuit for V-I acquisition, breakdown in gases, discharge regimes.

by oscilloscope, OES.

7. *Etching* - Reactive Ionic etching and Inductively coupled plasma

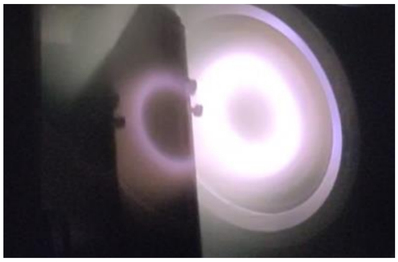
The objective is to design an etching process for silicon or SiO_2 etching, study the selectivity, and optimize the process to obtained a good profile.

- Etching process characterization using an RF capacitive discharge.
- Vary the parameters to optimize the etching of silicon and other materials. Comparison of the etch rate obtained by SEM and by profilometry.



Skills: Use of an inductively coupled plasma reactor, vacuum systems, process development, etching mechanisms, cryogenic systems, SEM characterisation, profilometry.

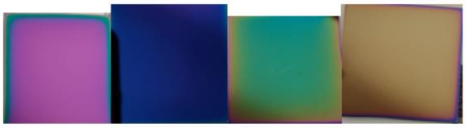
8. PVD – Thin film deposition by Physical Vapor Deposition



Deposition by PVD is commonly used in the industry to form thin metal layers. The aim is to study the film thickness and properties depending on the process conditions. Characterizations will be carried out using a SEM, profiolmeter, 4 tip probe. A study can be carried out on high aspect ratio structures to evaluate if the deposition is conform or not.

Skills: Use of a DC plasma reactor equipped with a magnetron, vacuum system, , deposition process, SEM characterisation, profilometry , 4 tip probe

9. *PECVD* – Dielectric layer deposition by Plasma Enhanced Chemical Vapor Deposition



The objective is to study the growth of a dielectric using a PECVD process. Two types of dielectric can be studied: SiO_2 or Si_3N_4.
The project will consist in modifying the recipes and see the effect on the deposited layer. An ellipsometer and a SEM wil be used to evaluate the deposited layer.

Skills: Use of a capacitively coupled plasma reactor equipped with a heating substrate holder, vacuum system, deposition process, SEM characterization, ellipsometry

3) ENGINEERING PROJECT : PHASE 1

Between September and December, every 2 weeks, each student will work on a project with other students on plasma engineering. Different projects will be proposed to the students at the beginning of the year. There will not be any class during these project periods. The project can be in collaboration with a company.

Students will have to write a report and defend it orally in December.

4) PROJECT WITH GREMI LAB (15 ECTS)

Between September and December, each student joins a **research team** to work on a dedicated project **in collaboration with GREMI lab** (e.g. plasma etching process, plasma for medical application, plasma deposition process, plasma diagnostics, microplasmas, …)
At the end, **the student will have to write a report and defend it orally**.

Note that the project with GREMI can be an extension of the “Engineering project: Phase 1”.

EMBEDDED SYSTEMS ENGINEERING PACKAGE

4th year- Master 1				
Fall Semester (September – December)		Course Unit code	Total Hours	ECTS
1	Courses and Board Design (microcontroller)	7GP04	**100h**	**8**
2	Engineering project	7GP07	**55h**	**6**
3	Supervised Project at Prisme Lab	POLUP15		**15**

Softskills available with this package :

4	English and science	7HP02	**40h**	**3**

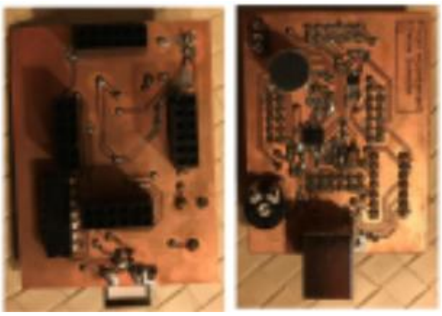
1) COURSES AND BOARD DESIGN (100H)

Unit	**Courses**	**Hours**
prerequisite reminders (7h30)	Number coding in embedded systems	1:15
	Compilation process	2:30
	Git lab	2:30
	tests	1:15
System control approaches (18h45)	Finite state machines	5:00
	Introduction to PID	11:15
	Tests	2:30
Hardware Architecture (12h30)	Part I	5:00
	tests	1:15
	Part II	5:00
	Tests	1:15
ATMEGA 328P Example (18h45)	Architecture and registers	2:30
	Lab : UART link principles and implementation	3:45
	Lab : SPI link principles and implementation	3:45
	Lab : I2C link principles and implementation	3:45
	Interruptions and timer	2:30
	tests	2:30
STM8 Example (16h15)	Architecture and registers	3:45
	Lab : UART link principles and implementation	3:45
	Lab : I2C link principles and implementation	3:45
	Lab : Sleep mode principles and implementation	3:45
	Tests	1:15

Board Design (26 hours with teachers + 50 hours in autonomy)

The goal is to design a daughter board for the STM8 discovery kit https://www.st.com/en/evaluation-tools/stm8s-discovery.html).

This daughter board will include :



- a microphone with an analog circuit to adapt, filter and amplify the acquired signal. The audio signal is connected to the STM8 ADC for sampling,
- an I2C magnetic sensor
- an UART/USB interface to connect a PC to the STM8S board.

The student will learn to :

1. read the datasheets, extract the useful information (pinout, constraints (voltage, current, power, size, dimensions...),
2. make a raw functional schematic where all these information will be indicated and write the Bill of Material (BOM).
3. create the schematic, then place and route with a Computer Aided Design (CAD) software (https://easyeda.com/)
4. print the daughter board PCB
5. debug & test the daughter board

2) Engineering Project (50h with Teacher + 100h in autonomy)

Within a team (maximum 4 students), the student will work on a real embedded system project (examples given below), from the early specifications to the proof of concept. An average of 1 day per week will be spent on that project.

Lessons on project methodologies will be given :

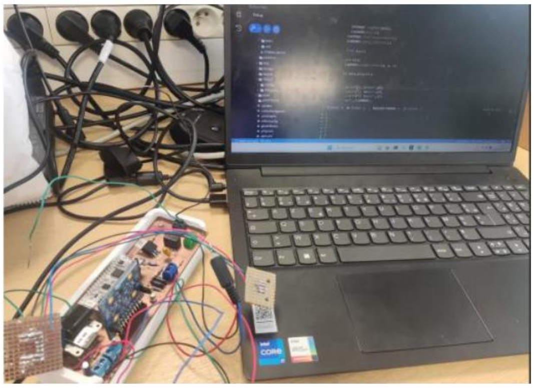
- introduction to project management through a serious-game,
- introduction to system architecture,
- a Model-Based Systems Engineering tools (Capella) will be presented.

A supervisor will be attached to the team. Regular meetings are planned to keep the team on track.

Three oral presentations are scheduled with several project committees :

1. an audit of the specifications and use cases by 2 external professional experts
2. an preliminary design review to validate the functional and technical design
3. a final presentation to present the proof of concept.

These oral presentations plus a final technical report will be evaluated.
Project examples :
- drone design
- Solar tracker
- autonomous forest monitoring system



-autonomous robot

3) PROJECT WITH PRISME LAB (15 ECTS)

Between September and December, each student joins a **research team** to work on a dedicated project **in collaboration with PRISME lab (AI – Signal - Image – Vision team).**
At the end, **the student will have to write a report and defend it orally**.

PRISME
Laboratoire Pluridisciplinaire de Recherche Ingénierie des Systèmes, Mécanique, Énergétique

Note that the project with PRISME laboratory can be an extension of the “Engineering project”.

Innovations in Design and Materials (ICM)

MULTIPHYSICS MODELING AND SIMULATION PACKAGE

5th year- Master 2				
Fall Semester (September – December)		Course Unit code	Total Hours	ECTS
1	Non- linear behaviour law	**9IC10**	**30h**	***3***
2	Advanced simulation	9IC13	**30h**	***3***
3	Composites simulation	9IC16	**30h**	***3***
4	Optimization and additive fabrication	**9IC22**	**30h**	***3***
5	Supervised Project in LAME lab	POLUP15	***150h***	**15**

Softskills available with this package :

4	Intercultural communication	9HM02	**22h30**	**2**
5	Intercultural communication start up project	9HM03	**10h**	**2**

5) SUPERVISED PROJECT IN LAMÉ LAB

Between September and December, each student joins a **research team** to work on a dedicated project.
At the end, **the student must write a report and defend it orally**.

LaMé
Laboratoire de Mécanique
Gabriel Lamé

Civil and Geo-environmental Engineering (GCGE)

SUSTAINABLE CONSTRUCTION PACKAGE

5th year- Master 2				
Fall Semester (September – December)		Course Unit code	Total Hours	ECTS
1	Structures under dynamic and environmental loads	9CD01	**70h**	**8**
2	BIM project	9CD04	**16h**	**6**
3	Supervised Project in LAME lab	POLUP15		**15**

Softskills available with this package :

4	Intercultural communication	9HC02	**22h30**	**2**
5	Intercultural communication start up project	9HC03	**10h**	**2**

1) STRUCTURAL ENGINEERING COURSES

Unit	**Courses**	**Hours**
Structures under dynamic and environmental loads	Durability of materials and structures	31.25 h lecture 12.5 tutorials 26.25 h labs
	Dynamics and Parasismics	
	Soil-structure interaction	
	Snow and wind loads	

2) BIM PROJECT

BIM project	BIM application of structural engineering	16 h labs 14 h autonomy

3) SUPERVISED PROJECT IN LAMÉ LAB

Between September and December, each student joins a **research team** to work on a dedicated project.
At the end, **the student must write a report and defend it orally**.
150 hours of project

Laboratoire de Mécanique Gabriel Lamé

GEO-ENVIRONMENTAL ENGINEERING AND SUSTAINABLE CITIES PACKAGE

5th year- Master 2				
Fall Semester (September – December)		Course Unit code	Total Hours	ECTS
1	Polluted sites and soils	9GE01	**45h**	**6**
2	Water Resource and Environment Management	9GE02	**30h**	**8**
3	Supervised Project in LAME lab	POLUP15		**15**

Softskills available with this package :

4	Intercultural communication	9HC02	**22h30**	**2**
5	Intercultural communication start up project	9HC03	**10h**	**2**

1) GEO-ENVIRONMENTAL ENGINEERING COURSES

Unit	Courses	Hours
Polluted sites and soils		25h lecture 12.5h tutorials 7.5h labs 8.75h autonomy

2) PROJECT

Water Resource and Environment Management	Vulnerability, risks	5 h lectures
	Field hydrology	3.75 lecture 5 h tutorials 3.75 h autonomy
	Water management	3.75 h lecture 6.25 tutorials
	Water and wastewater treatment	6.25 h lecture 12 h 50 autonomy

3) SUPERVISED PROJECT IN LAMÉ LAB

Between September and December, each student joins a **research team** to work on a dedicated project.
At the end, **the student must write a report and defend it orally.**

LaMé Laboratoire de Mécanique Gabriel Lamé

Technologies for Energy, Aerospace and Motoring sciences (TEAM)

AEROSPACE ENGINEERING PACKAGE

5th year- Master 2				
Fall Semester (September – December)		Course Unit code	Total Hours	ECTS
1	Turbulence and advanced CFD	9TE11	**47h**	**8**
2	Multiphysics coupling in aerodynamics	9TE12	**65h**	**8**
3	Guided experiments (part of 9TE11 and 9TE12)		***28h***	
4	Project with PRISME Lab	POLUP10	***150h***	***15***

1) TURBULENCE AND ADVANCED CFD (47H)

Unit	Courses	Hours
Turbulence and advanced CFD (9TE11 47h)	Statistical modelling of turbulence (RANS)	5 :00
	Physics of turbulence	5 :00
	Large-eddy simulation	6 :15
	CFD Labs	5 :00
	Experimental labs and signal analysis	11 :30
	CFD Project	5:00
	Conferences	5 :00
	Tests	4 :15

2) MULTIPHYSICS COUPLING IN AERODYNAMICS (65H)

Aeroacoustics (9TE12 26h15)	Sources of noise	2:30
	Transmition/ reflection and impedance/reactance	2:30
	Linearised acoustics	5:00
	Helmholtz theory	2:30
	Ray tracing and the dispersion relation	2:30
	Lighthill theory	2:30
	Ffowcs Williams Hawking theory	2:30
	RANS modelling	2:30
	CFD project	2:30
	Tests	1:15
Aeroelasticity (9TE12 13h75)	Static divergence	1:15
	Aileron reversal	1:15
	Introduction to linear and non-linear stability	1:15
	Vortex-induced vibration	1:15
	Aeroelastic galloping	1:15
	Aerodynamic flutter	1:15
	Experimental labs and signal analysis	2:30
	CFD labs	1:15
	CFD project	2 :30

Optimization in aerodynamics (9TE12 15h)	Gradient Methods for large-scale optimization problems	1:15
	Static problems	1:15
	Dynamical systems	1:15
	Time-dependents PDE (1D)	1:15
	Steady two-dimensional problems (2D)	1:15
	Navier-Stokes equations	1:15
	Data assimilation	1:15
	Sensitivity methods and shape-optimisation	1:15
	CFD labs	2 :30
	CFD project	1 :15
	Tests	1 :15
Introduction to high-enthalpy flows (9TE12 10h)	Use of the thermophysical properties of gases	2:30
	Predict the reentry trajectory of simple objects	2:30
	FORTRAN lab	2:30
	Tests	2:30

GUIDED EXPERIMENTS (28 HOURS WITH TEACHERS + 30 HOURS IN AUTONOMY)

These guided experiments complete the 2 courses 9TE11 and 9TE12. They are dedicated to teaching experimental methods, simulations and physical analyses in aerospace engineering. They offer hands-on practice and allow students understanding **theoretical concepts** of aerospace dedicated courses.

Each group of 2 to 4 students will work in teaching and research wind tunnels. Each project will last **a day**. They will be supervised by **professors** and a **research engineer**. One of the projects will be organized in the **research facilities of the PRISME laboratory.**

Competences for each project:

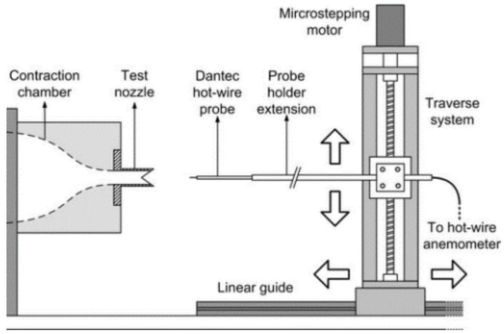
	JET	BF-RAMP	WING	JET	BF-RAMP	WING
RANS	✓	✓	✓	✓	✓	
LES	✓	✓			✓	
SIGNAL	✓	✓		✓	✓	✓
BUDGET	✓	✓		✓	✓	✓
ACOU	✓		✓			
STRUCT			✓			✓
OPTIM		✓	✓		✓	
COMP	✓			✓		
	Numerical simulations (FLUENT)			Wind tunnel		

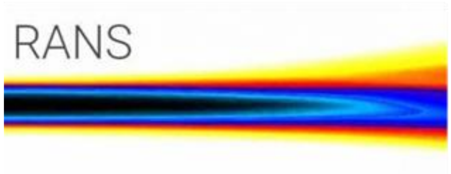
RANS: Reynolds Averaged Navier-Stokes
LES: Large-eddy simulation
SIGNAL: Signal analysis
OPTIM: Optimization methods
ACOU: Acoustics and Aeroacoustics
STRUCT: Structural coupling
COMP: Compressible flows

1. Self-similar analysis of a turbulent jet

The objective of this project is to analyze the behavior of a turbulent jet using both experiments and numerical simulations. The lab sessions comprise of traverse measurements obtained in the wind tunnel while numerical simulations are performed using the Fluent software package:

- Perform a statistical analysis of the data obtained from the hot-wire probe.
- Analyze the mass and momentum budget of the turbulent jet following different locations using the Reynolds-averaged approach.
- Provide a complete self-similar analysis of the turbulent jet.
- Perform the same analysis using the simulation software Fluent and analyze the differences between numerical simulations and experimental results.



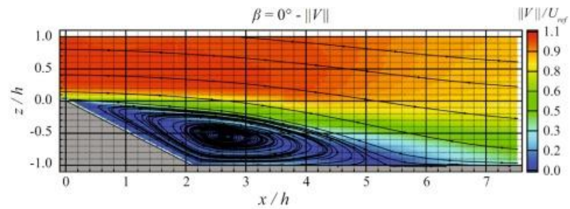


Skills: Learn how to calibrate and perform measurements using a hot-wire anemometer. Collect and analyze point-wise measurements and profiles using MATLAB. Analyze the physical characteristics of the flow. Replicate the experiment in a simulation and provide a critical analysis of the results.

2. *Separated flow over a slanted ramp (CFD vs. exp)*

The objective of this project is to analyze the separated flow over a slanted 25° backward-facing step. This part combines lab experiments with Reynolds-averaged and Large-eddy numerical simulations of a turbulent flow using different

- Perform experiments and data collection from a research wind tunnel. Analyze pressure measurements, hot-wire, and particle image velocimetry data. Perform data analysis to identify the physical scales driving the problem.
- Learn how to accurately simulate this challenging flow problem and select the right Reynolds averaged turbulence model.
- Learn how to setup and run a large-eddy simulation and compare the data with the experiment and the RANS approach.



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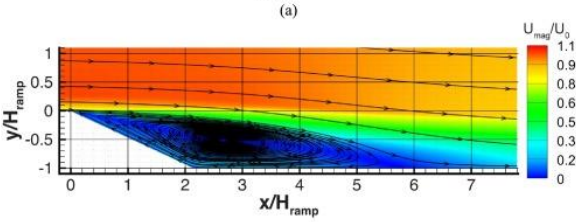


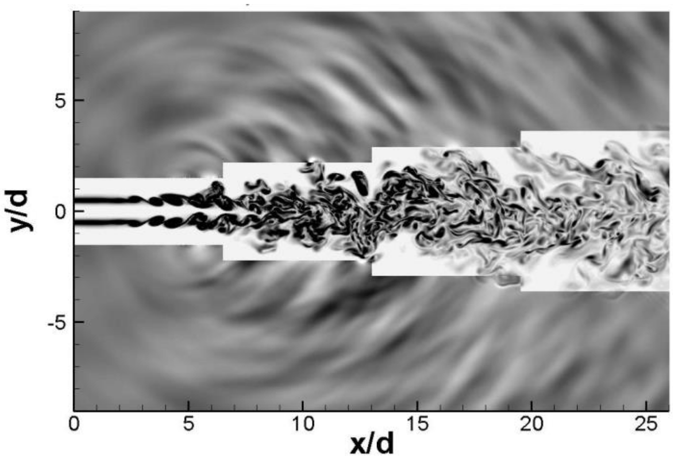
(b)

Skills: Conduct the analysis of a separated turbulent flow using planar measurements based on PIV and near-wall hot-wire measurements. Decide on the right scaling approach to diagnose the forces acting on the model. Select the appropriate tool for simulation. Diagnose the limits of the physical modelling approach, setup and analyze a state-of-the-art numerical simulation and assess the quality using laboratory experiments.

3. *Noise simulations (jet/cavity/wing)*

The objective of this project is to analyze the mechanisms leading to sound generation by different geometries and appropriately simulate the sounds pressure level in the case of a compressible flow over a jet or a cavity or a trailing edge.

- Learn how to setup unsteady aeroacoustics simulations.
- How to calculate the noise generated by these configurations.

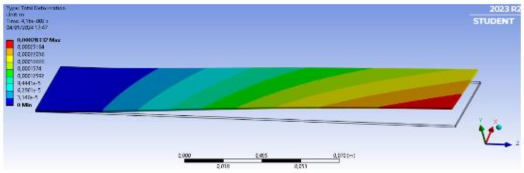


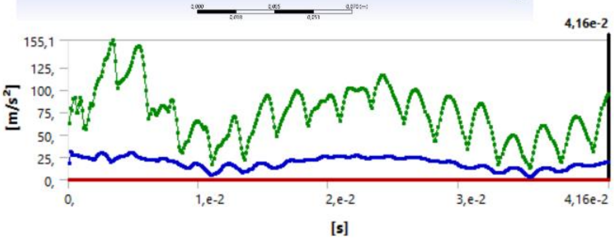
Skills: Simulate and predict the sound generated by specific configuration.

4. **Aerodynamic flutter analysis (exp. vs. CFD)**

The objective is to model theoretically, simulate, and measure the flutter phenomena on a flexible wing. The theorical model derived in class is used to discriminate between aeroelastic galloping and the flutter phenomena. Hot-wire measurements and image analysis from a fast camera are used to obtain the amplitude and frequency of the oscillations which are finally compared with the theoretical model.

- Perform aeroelastic measurements on a structure in a wind tunnel.
- Data analysis from hot-wire anemometry and image analysis.
- Perform simulations using and Ansys and couple with Fluent to simulate fluid-structure interactions.

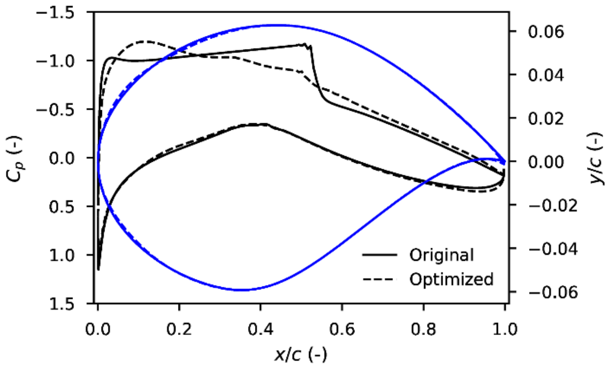




Skills: Predict and anticipate the design of flexible structures such as airframes wind turbines, and more general structures.

5. *Sensitivity analysis and shape optimisation (CFD)*

The objective of this project is to improve the shape of a wing for a particular set of operating condition.
- Learn how to setup a numerical simulation for the case of a wing using a RANS approach.
-. Learn how to fine tune the RANS model using data gathered from the literature (pressure and forces) to accurately predict the base flow.
- Learn how to setup and run a sensitivity analysis and a shape-optimization procedure.
- Analyze the results and understand the role of the shape modification on the flow.



Skills: Use the optimization modules in fluent based on the sensitivity of the adjoint equations.

1) PROJECT WITH PRISME LAB (15 ECTS)

Between September and December, each student joins a **research team** to work on a dedicated project **in collaboration with PRISME lab/Polytech** (e.g., physical analysis of turbulent shear flows, flow control, innovative surfaces, …)
At the end**, the student must write a report and defend it orally**.

PRISME
Laboratoire Pluridisciplinaire de Recherche Ingénierie des Systèmes, Mécanique, énergétique

Other courses partially or fully taught in English at Polytech Orleans

Signification of the symbols

Proportion of teaching taught in English

- 🏳 : materials provided in English, course taught in French
- 🏳🏳 : 50% in English
- 🏳🏳🏳 : fully taught in English

Sustainable Development and Social Responsibility (SDRS)

- 🌍 : mentioned
- 🌍🌍 : issues visible in Teaching Unit (TU) competences
- 🌍🌍🌍 : taking into account standards and regulations in the Teaching Unit (TU)

Support for innovation, entrepreneurship and takeover

- 🖉 : mentioned
- 🖉🖉 : issues visible in Teaching Unit (TU) competences
- 🖉🖉🖉 : mastery of standards and regulations in the Teaching Unit (TU)

Technologies for Energy, Aerospace and Motoring sciences (TEAM)

Technologies for Energy, Aerospace and Motoring Sciences

4TH YEAR / MASTER 2 COURSES

TU Code	Title of the Teaching Unit (TU)	Learning hours	*ECTS*
TECHNOLOGIES for ENERGY, AEROSPACE and MOTORING SCIENCES (TEAM)			
4th year TEAM 1st semester (September – January) S7			
7HT02	English and science	**40**	***3***
7TE01	Energy Management	**117,5**	***9***
7TE02	Fluid dynamics	**117,5**	***9***
7TE03	Electrical engineering and automatic control	**67,5**	***6***
4th year TEAM 2nd semester (January – April) S8			
8HT01	Business English	**40**	***4***
8TE01	Assistant Engineer Project	**5**	***4***
8TE02	Engine and propulsion systems	**120**	***9***
8TE03	Numerical and experimental tools for the engineer	**45**	***4***

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **7HT02** **Semester 7**

English and science

Supervisor: Sybilla DUBOIS **ECTS: 3**

Skills

At the end of this course, engineering students will be able to:

- Practise communicating in English on a scientific or technical subject, orally, in writing and by visual means

Syllabus

- Learn how to write a CV and cover letter in English by studying documents, the work of young engineers, as well as the websites of various companies in the field.
- Discuss an invention and how it works and its potential evolution
- Discuss and promote a product or gadget related to your field of activity and/or write technical documentation corresponding to the project
- Study and understand audio and visual scientific documents related to their field of engineering;
  Express themselves orally and in writing: writing exercises and oral expression activities using technical and scientific structures and vocabulary
- Take part in discussions and/or debates on science, environment, climate, policy, etc.
- Final project: participate in a shared virtual project using your area of expertise

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
0h00	0h00	40h00	0h00	0h00

In person teaching: 40h00

Taught in English: **SD/SR:** **Innovation:**

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **7TE01** **Semester 7**

Energy Management

Supervisor: Christian CAILLOL **ECTS: 9**

Skills

At the end of this course, engineering students will be able to:

- Use the essential tools to assess the different potential energy sources (from conventional or renewable resources), whether for energy production (thermal or motor systems) or energy-saving strategies in buildings.
- Apply the main principles of acoustic treatment to building interiors or noisy devices.

Syllabus

The main challenges for tomorrow's energy and renewable energies

Primary resources, final energy consumption in France and worldwide and its impact on the climate. Solar thermal energy: sizing of collectors. Wind energy. Eco-design: principles of life cycle analysis. Bio-fuels.

Thermal design of buildings

Thermal optimization of buildings, thermal regulation RE2020. Introduction to HVAC engineering: air exchange, air conditioning.

Vibration and acoustics

Determining the vibration modes of simple elements, the reflection and transmission coefficients of acoustic waves. Determining the resonance modes in a room and identifying solutions to dampen them.

Industrial combustion

Definition and determination of characteristic combustion parameters. Fuels and oxidizers: stoichiometric combustion equation, equivalence ratio. Analysis of pollutant emissions. Combustion heat and temperature.

Labs in energetics

Measurement of flame front velocity and stability diagram. Calorimetry: measurement of the heat of combustion. Study of the efficiency of a solar collector. ThermOptim software: study of a heat pump.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
55h00	25h00	37h30	5h00	0h00

In person teaching: 117h30

Taught in English: 🏳🏳 **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **7TE02** **Semester 7**

Fluid dynamics

Supervisor: Nicolas MAZELLIER **ECTS: 9**

Skills

At the end of this course, engineering students will be able to:

- Understand the physical principles of fluid dynamics and heat transfer in different regimes. Being able to apply them in simple configurations.
- Identify and classify the main types of flows encountered in aerodynamics and understand their effects on aerodynamic performance.
- Learn about digital and experimental tools in academic or industrial configurations. Being able to choose the most suitable physical models. Know how to carry out an experiment/simulation and criticize the results.

Syllabus

1. Gas dynamics
Reminder of the equations of motion and energy. Highlighting dimensionless numbers and the notion of similarity. Introduction to compressible flows in perfect fluid; isentropic relationships; shock waves; study of the Laval nozzle.
2. Boundary layer
Dynamic and thermal boundary layer theory, self-similar solutions and scaling laws. Dimensionless numbers characteristic of heat transfers. Reynolds analogy.
3. External aerodynamics
The main phenomena: attached and separated, 2D and 3D, subsonic and supersonic flows. Case of the profile and the wing in incompressible. Linearized potential in compressible; 2D sub and supersonic applications. Application to vehicles and energy systems.
4. Turbulence
Introduction to turbulence. Statistical approach through the Reynolds formalism (RANS).
Highlighting the closure problem and introducing the turbulent viscosity model.
5. Experimental practical work
Getting started with measuring instruments in fluid dynamics. Development of a boundary layer. Laminar/turbulent transition. Simple body aerodynamics. Laval nozzle.
6. Numerical practical work
Simulation of turbulent flows on the ANSYS software suite. Getting started with simple cases. Wing profile from Mach 0.3 to Mach 3. Laval nozzle.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
50h00	32h30	35h00	8h45	0h00

In person teaching: 117h30

Taught in English: 🏳🏳 **SD/SR:** 🌍 **Innovation:** ✎✎

Technologies for Energy, Aerospace and Motoring Sciences (TEAM)	7TE03	Semester 7

Electrical engineering and automatic control

Supervisor: Guillaume COLIN **ECTS: 6**

Skills

At the end of this course, engineering students will be able to:

- Modeling 4 electrical machines by their equivalent schemes; associating loads to rotating machines by their mechanical characteristics; measuring electrical powers on networks with linear or non-linear loads; understanding the risks at low voltage below 500 V; implementing the 4 electrical machines; recording the mechanical characteristics of two rotating machines associated with their converter or scalar inverter
- Study of continuous linear dynamic systems and synthesizing equalizers; modeling and identifying a linear system from data; identifying the inputs and limitations of a closed-loop control system; adjusting and operating a PID, introduction to advanced industrial controls

Syllabus

Electrical Engineering

Active, reactive and deforming apparent powers on linear and non-linear loads; elements of magnetism applied to current transformers, linear inductances and no-load current of a voltage transformer; ferromagnetic losses and technological solutions. 4 electrical energy conversion machines. Transformer. DC machine, AC machines, synchronous and asynchronous.

Automatic control

Introduction and recaps: definitions, synthesis of a control system. Basic models and responses. Dynamic performance of corrected systems.
Continuous control: principles, role, effects and use. Synthesis of PID correctors: tuning, industrial structure. Delayed process, internal model control.

Labs

Three-phase power measurements and protection of persons; Three-phase transformer; Direct current machine; Asynchronous machine; Speed variation on an asynchronous machine; Synchronous machine and alternator starter test bench; PID regulation of the thermal behavior of a building.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
16h15	13h45	37h30	13h45	0h00

In person teaching: 67h30

Taught in English: 🏳🏳 **SD/SR:** 🌍 **Innovation:** ✎

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **8HT01** **Semester 8**

Business English

Supervisor: Isabelle BEN CHAABANE **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Use English in the corporate world
- Reach the B2+ level

Syllabus

1 - Business English

Various activities involving the use of corporate vocabulary and skills:
- Job interview simulations
- Study of company organigrams, portraits of CEOs, management styles and corporate cultures
- Meetings and telephoning
- "Project": Reading and study of a book in English dealing with societal and economic stakes

2 - TOEIC Preparation

2 mock TOEICs. Revision of key grammatical and lexical points

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
0h00	0h00	40h00	0h00	0h00

In person teaching: 40h00

Taught in English: 🏳🏳🏳 **SD/SR:** **Innovation:**

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **8TE01** **Semester 8**

Assistant Engineer Project

Supervisor: Ivan FEDIOUN **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Apply for an assistant engineer position (CV, cover letter, interview)
- Analyze a customer's needs and expectations and propose a suitable cost-effective solution
- Build on and consolidate the disciplinary skills acquired during the first two years of training to respond technically to the needs of the project
- Plan and optimize work (independently and as part of a team) in order to meet performance and meet deadlines

Syllabus

Project team recruitment

- Consult offers submitted by project managers
- Build your CV and cover letter accordingly
- Applying for jobs and preparing for interviews

Project Management

- Introduction to the information retrieval tools required for project management
- Introduction to drawing up quotations and scientific technical appendices
- Introduction to audit principles

Technical implementation support in collaboration with project managers
Design and production of experimental and/or digital databases
Contribute to writing technical reports
Attendance at progress meetings
Assessment of acquired skills (written + oral)

Grading

Thesis, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
0h30	3h45	0h45	86h15	0h00

In person teaching: 5h00

Taught in English: **SD/SR:** **Innovation:**

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **8TE02** **Semester 8**

Engine and propulsion systems

Supervisor: Pierre BREQUIGNY **ECTS: 9**

Skills

At the end of this course, engineering students will be able to:

- Understand the main parameters impacting the operation of an internal combustion engine (ICE)
- Carry out an analysis of the cimbustion process in an ICE
- Carry out the pre-sizing of an air breating or rocket propulsion system

Syllabus

Internal Combustion Engine

Thermodynamic cycles, efficiencies, energy calculation
Study of the compression phase, assess wall heat losses, wall temperature, hypothesis & limits
Heat Realease and Heat Release rate (HRR) calculation growth and net, wall heat losses, energy model closure
HRR Wiebe model, premixed and diffusion combustion. Adjusting the model to fit experimental data
Lab session on engine test benches

Aircraft and Rocket Propulsion

Main components, architecture, principles
Thermodynamic and mechanical sizing of a turbojet/fan
Performances calculation of rocket and aircraft engines
Projetcts on a virtual engine test bench: control and thermodynamics

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
61h15	6h15	52h30	18h45	0h00

In person teaching: 120h00

Taught in English:⚐⚐⚐ **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **8TE03** **Semester 8**

Numerical and experimental tools for the engineer

Supervisor: Pierre-Yves PASSAGGIA **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Select a particular type of sensor to measure a specific type of physical phenomenon.
  Perform the acquisition and visualisation of a signal from an experiment. Numerical analysis of different signals (statistics, spectral analysis, filtering)
  Interpolate, approximate and integrate multivariate functions.
  Perform optimisation methods to determine local and global minima using simplex and Lagrange multipliers methods.

Syllabus

Signal acquisition and processing

- Signal processing: Fourier analysis, auto- and cross-correlations, Parseval and Wiener theorem, introduction to wavelets.
- Lab sessions using Matlab: Acquisition, and visualisation of a signal using a microphone. Processing and analysis from acoustics, engines, and fluid mechanics.
- Sensor technology and acquisition methods.

Interpolation and filtering

- Interpolation, nodal approximation, polynomial expansions, spline methods.
- Numerical integration.
- Least-squares methods.

Optimisation

- Local and global minima analysis of multivariate functions.
- Constrained optimisation.
- Lagrange multipliers method.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
16h15	0h00	28h45	6h15	0h00

In person teaching: 45h00

Taught in English: **SD/SR:** **Innovation:**

Technologies for Energy, Aerospace and Motoring Sciences

5TH YEAR / MASTER 2 COURSES

TU Code	Title of the Teaching Unit (TU)	Learning hours	*ECTS*
TECHNOLOGIES for ENERGY, AEROSPACE and MOTORING SCIENCES (TEAM)		**732,50**	***60***
5th year TEAM 1st semester (September- December) S9		**282,50**	**30**
1 English Teaching Unit according to validated TOEIC level			
9HT02	Intercultural communication	**22,5**	***2***
9HT03	Intercultural communication debating society	**10**	***2***
2 Teaching Unit amongst 5			
9TE11	Turbulence and advanced CFD	**70**	***8***
9TE12	Multiphysics coupling in aerodynamics	**70**	***8***
9TE13	Combustion and applications	**70**	***8***
9TE14	Control of Energetic System	**70**	***8***
9TE15	Energetic systems	**70**	***8***
To be chosen according to status			
9TE16	Engineer project - phase 1	**100**	***9***
5th year TEAM 2nd semester (January – September) S10		**450**	**30**
To be chosen function of S9			
ATE05	Engineer project - phase 2	**70**	***3***
1 Teaching Unit amongst 3			
ATE02	Gas dynamics	**70**	***5***
ATE03	Powertrain	**70**	***5***
ATE04	Buildings energy	**70**	***5***
ATE06	Engineer project	**170**	***10***

Technologies for Energy, Aerospace and Motoring Sciences (TEAM)	9TE11	Semester 9

Turbulence and advanced CFD

Supervisor: Ivan FEDIOUN **ECTS : 8**

Skills

At the end of this course, engineering students will be able to:

- Describe, understand, and analyse turbulent flow phenomena.
- Use the necessary tools for the analysis of experimental databases and numerical simulations.
- Select and perform different levels of descriptions/physical modelling (ILES, LES, DES, RANS) upon available computing resources.
- Use the ANSYS/FLUENT software suite for the simulation of turbulent flows and their optimisation.

Syllabus

Experimental labs and signal analysis

Grid and jet turbulence, hot-wire measurements - Signal analysis of experimental data (spectral analysis, first-to-fouth order statistical moments). Analysis of PIV databases (provided by the professor).

Statistical modelling of turbulence (RANS)

Statistical tools - Reynolds- Averaged Navier-Stokes equations - Closure problem and solutions - Transport equations of turbulent quantities - Newtonian closure and its consequences - Turbulent viscosity models - Wall laws.

Physics of turbulence

One-point/two-point statistics - Eulerian microscales integral lengthscales - Energy and enstrophy spectra in homogeneous and isotropic turbulence - Kolmogorov theory (K41).

Large-eddy simulation

Explicit and implicit filtering - Filtering induced by the numerical scheme - Sub-grid scale modelling for large-eddy simulations.

CFD Labs

RANS and LES simulations, shape and turbulence model optimisation.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
28h45	0h00	31h15	0h00	10h00

In person teaching: 70h00

Taught in English: 🏳🏳🏳 **SD/SR:** 🌍🌍 **Innovation:** 🖉

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **9TE12** **Semester 9**

Multiphysics coupling in aerodynamics

Supervisor: Pierre-Yves PASSAGGIA **ECTS: 8**

Skills

At the end of this course, engineering students will be able to:

- Describe fundamental physical phenomena associated with aeroacoustics (aerodynamic noise), aeroelasticity (fluid-structure interaction), and high-speed flows (where high enthalpies are reached).

Syllabus

Aeroacoustics

General concepts of aerodynamic noise, fields of application, sound propagation in the presence of flow in an inhomogeneous medium, methods for calculating radiated noise, noise sources, interaction between flow and acoustics

Aeroelasticity

Description and analysis of steady and unsteady aerodynamics coupled to deformable structures, key physical characteristics of the statics and dynamics of objects (airfoils, wings, building), subject to elastic, inertial, and aerodynamic forces, at the origin of static divergence and aerodynamic flutter:

High-speed aerodynamics

Description, analysis, and simulation of very high-speed flows where heating effects dominate aerodynamics, for instance, during reentry flight phases and hypersonic flight regimes.

Adjoint-based sensitivity analysis

Mathematical techniques for Lagrangian-based sensitivity analysis of physical models towards optimisation and flow control. Mathematical analysis of sensitivity equations for optimisation and physical analysis. Application to static, dynamic, nonlinear and 3D unsteady problems. Shape and turbulence models optimisation.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
27h30	42h30	0h00	6h15	0h00

In person teaching: 70h00

Taught in English:🏳🏳🏳 **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎✎

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **9TE13** **Semester 9**

Combustion and applications

Supervisor: Christine MOUNAIM-ROUSSELLE **ECTS : 8**

Skills

At the end of this course, engineering students will be able to:

- Acquire the requisite knowledge to describe, understand and analyze laminar and turbulent combustion phenomena involving 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 turbines. 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 (measurement techniques and post-processing tools).

Syllabus

Theory

Combustion chemistry (thermodynamics applied to chemistry, chemical kinetics) ; Self-ignition (theory, measurement methods, examples of detailed modeling) ; Premixed and diffusion flames (flammability limit, flame stabilization, extinction parameters, propagation velocity, flame thickness, …) ; Flame/turbulence interactions ; Models for premixed and diffusion turbulent flames ; Combustion high-energy materials and explosives ; Pollutant formation and post-treatment systems ; Examples of combustion phenomena and pollutant formation with recent technologies ; Introduction to experimental techniques allowing to characterize a reactive or non-reactive turbulent eddy flow

Practice

Use of Image processing (Matlab); Use of CHEMKIN software (chemical kinetic) ; Application of notions tackled through 3D calculation codes (FLUENT or CONVERGE)

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.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
37h30	3h45	28h45	2h30	0h00

In person teaching: 70h00

Taught in English: 🏳🏳 **SD/SR:** 🌍🌍 **Innovation:** 🖉

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **9TE14** **Semester 9**

Control of Energetic System

Supervisor: Guillaume COLIN **ECTS: 8**

Skills

At the end of this course, engineering students will be able to:

- Master engine control systems, control strategies and the associated control devices (sensors, actuators, controllers);
- 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 (heuristic, optimal).

Syllabus

Theory

- History of engine control: carburetor, mechanical injection
- State of the art: sensors, actuators, hardware and software, strategies...
- Spark ignition engine control: basic strategies, pollution, knock, idle, start, cold start, drivability...
- Diesel engine control: history, high pressure pumps and injectors, common rail control
- Control Development methods. Embedded networks. Embedded models
- 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)

Practice

- Tuning an internal combustion engine: 3 labs including 2 on a real engine test bench
- Engine control: 3 labs, 1 of which on an actuator bench system and 1 on a real engine test bench
- Energy management of an hybrid vehicle (1 lab on a roller bench)

Mini-project

Pre-sizing the technical elements of an Hybrid Electric Vehicle and designing the energy management with the softwares Amesim and Simulink.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
17h30	0h00	52h30	28h45	0h00

In person teaching: 70h00

Taught in English: 🏳🏳🏳 **SD/SR:** 🌍 **Innovation:** ✏✏

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **9TE15** **Semester 9**

Energetic systems

Supervisor: Camille HESPEL **ECTS: 8**

Skills

At the end of this course, engineering students will be able to:

- Size of power generation systems
- Apply the concepts of security and nuclear safety
- Use business software to perform a life cycle analysis

Syllabus

Energy geopolitics

- Situation and issues: primary energy, eqCO2 emissions, standard, 1.5°C objective
- Energy mix: nuclear, renewable energy, other
- Role of new energy carriers: hydrogen, ammonia

Renewable energies

- Photovoltaics: technology and sizing
- Wind power: technology and sizing
- Solar thermal: technology, sizing and return on investment

Advanced thermodynamics

- Joule cycle and cogeneration
- Rankine cycle with or without superheat

Life cycle analysis

- Introduction to software (Gabi, simapro or greet)
- Compare different scenarios

Visit to a plant or company

Sites already visited: nuclear and thermal power plant, wood-fired heating plant, Artenay sugar refinery, La Renardière site (EDF), photovoltaic plant, POWIDIAN company

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
50h00	20h00	0h00	11h15	0h00

In person teaching: 70h00

Taught in English: 🏳🏳 **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **9TE16** **Semester 9**

Engineer project - phase 1

Supervisor: Ivan FEDIOUN **ECTS : 9**

Skills

At the end of this course, engineering students will be able to:

- Conduct an engineering project to answer an industrial or research problem.
- Develop, consolidate, and apply the skills developed during the engineering curriculum.
- Establish technical specifications, and management plans, and work autonomously.
- Regular follow-up meeting organisation with the industrial/academic partners.
- Syntethise work progress and deliver both presentations and written reports.

Syllabus

Project Phase 1

- Project selection.
- Contact the industrial or academic partner and establish the technical specifications of the study.
- Tasks and meeting planning.
- Tools and resource identifications that are required to accomplish the tasks.
- Risk and alternative solutions planning.
- Technical work realisation for each task.
- Update on work advancement, providing backup solutions when necessary.

Grading

Thesis, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
0h00	12h00	0h00	1h15	0h00

In person teaching: 12h00

Taught in English: 🏳🏳🏳 **SD/SR:** 🌍🌍🌍 **Innovation:** 🖉🖉🖉

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **ATE02** **Semester 10**

Gas dynamics

Supervisor: Azeddine KOURTA **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Have acquired a comprehensive understanding of the physical phenomena present in flows at speeds ranging from high subsonic to hypersonic.
- Understand the mathematical properties of Euler's equations (hyperbolicity, characteristics) in numerical shock-capture schemes (FVS, FDS). The main schemes. Initiation into FORTRAN programming.

Syllabus

Part 1: Dynamics of high-speed

- Recap of the 4th year course on thermodynamics, the Euler system, straight shocks
- 1D instationary flows: characteristics, Riemann invariants, shock tube; solution to the Riemann problem
- 2D stationary flows: oblique shocks, intersection of shocks, Mach disc. Expansion fan, Prandtl-Mayer equation, Linearized supersonic theory, Characteristics, Cauchy problem

Part 2: Numerical methods to solve Euler's equations

- Scalar hyperbolic conservation equations: characteristics and compatibility relation, monotone conservative schemes. Weak solutions and Rankine-Hugoniot condition. Entropy solutions
- Recap on the Euler 1D system: conservative variables, primitives, characteristics, transition matrices, Riemann invariants
- First-order 'upwind' finite-volume schemes based on flow decomposition (FVS) and approximate Riemann solvers (FDS)
- Second-order extension: MUSCL approach, TVD schemes and flow limiters

Part 3: Machine applications in FORTRAN

- Linear convection: programming, management of the boundary conditions
- Burgers' equation: Riemann problem with compressive or expansive initial conditions. Programming Lax-Friedrichs schemes and CIR with a constant time-step
- The Sod shock tube with fixed boundary conditions. Non-reflective, reflective , mixed boundary conditions. Roe scheme with Harten's entropy correction, adaptive time-step

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
25h00	45h00	0h00	12h30	0h00

In person teaching: 70h00

Taught in English:⚐⚐⚐ **SD/SR:** 🌍🌍 **Innovation:** 🖉🖉

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **ATE03** **Semester 10**

Powertrain

Supervisor: Pascal HIGELIN **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Understand physical and chemical processes during combustion and scavenging in internal combustion engines.
- Understand the reactions of a powertrain when changing its operating parameters using modeling.
- Build an internal combustion engine model. Optimise powertrain sizing and settings under efficiency, power output and emission constraints.
- Understand electrified powertrain energy management

Syllabus

Combustion

Thermochemistry and chemistry kinetics applied to combustion. Internal combustion engines aerodynamics. Air/fuel mixture preparation. Auto ignition. Premixed and diffusion flames.

Thermodynamic models

Classification of thermodynamic models. Validity limits. One zone, 2 zones and multizone models. Heat losses to the walls.

Combustion models

Semi-empiric Vibé model. Physical combustion models in spark ignition engines. Physical combustion models in compression ignition engines.

Turbocharging

Static and dynamic turbocharger models. Compressor / turbine adaptation. Pumping limit.

Electrification

Global characteristics of electric machines. Series, parallel, power split hybridization. Batteries and energy management. CAN network and powertrain supervision.

Grading

Written exam, Oral exam, Report

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
22h30	42h30	0h00	0h00	5h00

In person teaching: 70h00

Taught in English: ⚐⚐⚐ **SD/SR:** 🌍🌍🌍 **Innovation:** 🖉🖉

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **ATE04** **Semester 10**

Buildings energy

Supervisor: Jean-Michel FAVIE **ECTS : 5**

Skills

At the end of this course, engineering students will be able to:

- Identify the professional elements (human, technical) linked to the work of a project manager specialized in renewable energy and building heat transfer.
- Manage the different norms, state of the art of technology (current and sustainable), innovative production techniques, and environmentally friendly practices.

Syllabus

Environnemental norms, reglementations and requirements

Thermal control, durable architecture, agenda XXI. Project management. Environmental footprint and life cycle analysis.

Audit and thermal diagnostics

Environmental audit, energy-performance diagnostics, carbon footprint budget. Project management assistant and eco-friendly improvements

Passive energy

Classical and bio-sourced materials. Architecture, screens, waterspout wall.

Renewable energies

Solar-thermal heating, wind turbines, geothermal and bio-mass, energy mix.

Heat exchangers

Wood energy and heat pumps.

Grading

Written exam, Oral exam, Report

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
40h00	26h15	3h45	29h00	0h00

In person teaching: 70h00

Taught in English:⚐⚐⚐ **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎✎

Technologies for Energy, Aerospace and Motoring Sciences (TEAM) **ATE05** **Semester 10**

Engineer project - phase 2

Supervisor: Ivan FEDIOUN **ECTS : 3**

Skills

At the end of this course, engineering students will be able to:

- Conduct an engineering project to answer an industrial or research problem.
- Develop, consolidate, and apply the skills developed during the engineering curriculum.
- Establish technical specifications, and management plans, and work autonomously.
- Regular follow-up meeting organisation with the industrial/academic partners.
- Synthethise work progress and deliver both presentations and written reports.

Syllabus

First part : corresponds to "Phase 1"

Second part : Tasks completion, presentations and deliverables

- Team selection (with 4th year students), presentation of the previous work done and tasks allocation.
- Technical work realisation.
- Update on the advancement of the project with backup solutions if necessary.
- Deliverables including the final report and oral presentation of the final product/results.

Grading

Thesis, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
0h00	10h00	0h00	3h45	0h00

In person teaching: 10h00

Taught in English: 🏳🏳🏳 **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎✎

Automotive Engineering for Sustainable Mobility (AESM)

TU Code	Title of the Teaching Unit (TU)	Learning hours	ECTS
AUTOMOTIVE ENGINEERING for SUSTAINABLE MOBILITY (AESM)		**664**	***60***
1st year AESM - Semester 1		**347**	***30***
1AE01	Trends in Automotive Transportation and Sustainable Mobility	**10**	***1***
1AE02	Scientific pre-requisite	**50**	***5***
1AE03	Electrical engineering	**50**	***5***
1AE04	IT: programming	**50**	***5***
1AE05	Advanced physics	**50**	***5***
1AE06	French culture and language	**70**	***4***
One Teaching Unit of your choice according to option ECM or VDIV			
1AE07	Vehicle Dynamics 1	**65**	***5***
1AE08	Internal combustion engines	**65**	***5***
1st year AESM - Semester 2		**317**	***30***
2AE01	Acquisition systems and signal processing	**50**	***5***
2AE02	Real Time Programming	**50**	***5***
2AE03	Control and simulation of powertrains	**35**	***5***
2AE04	Project	**130**	***10***
One Teaching Unit of your choice according to option ECM or VDIV			
2AE05	Control and on-board diagnostics applied to internal combustion engines	**50**	***5***
2AE06	Control and on-board diagnostics applied to vehicle dynamics	**50**	***5***

Automotive Engineering and Sustainable Mobility (AESM) **1AE01** **Semester 1**

Trends in Automotive Transportation and sustainable Mobility

Supervisor: Luis LE MOYNE **ECTS: 1**

Skills

At the end of this course, engineering students will be able to:

- Understand transport geo-politics.
- Understand the inventory of resources.
- Recognize operational actors in the transport sector.

Syllabus

- Sustainable mobility.
- Environmental incentives.
- Well-to-wheels CO2 analysis.
- Areas for technology improvements.

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
10h00	0h00	0h00	1h15	0h00

In person teaching: 10h00

Taught in English: 🏳🏳🏳 **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎✎

Automotive Engineering and Sustainable Mobility (AESM) **1AE02** **Semester 1**

Scientific pre-requisite

Supervisor: Meryem JABLOUN **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Acquire skills and an understanding of mathematical tools necessary for studying and exploring characteristics of linear systems.

Syllabus

Fourier series decomposition

Perform Fourier Series decomposition on continuous-time periodic signals and understand Gibbs phenomenon

Linear differential equations

Solve linear differential equations: 1st and 2nd order cases: illustration and application to physical systems

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
28h45	21h15	0h00	1h15	0h00

In person teaching: 50h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **1AE03** **Semester 1**

Electrical engineering

Supervisor: Emmanuel BEURUAY **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Understand electrical and magnetism principles occurring in electrical motors divided in two parts: electrical motors and the dedicated converters.
- Understand the inner working of continuous and synchronous motors.
- Quantify the electrical efficiencies using active power, reactive power, apparent power, distortion power and power factor.

Syllabus

- Power: quantifying yields and efficiencies.
- Active, reactive, apparent, distortion power, power factor.
- Three phased system grid.
- Harmonic aspects in power and electromagnetic pollution.
- Magnetism applied to electrical motors. Loss reduction in permanent magnet rotors of synchronous machines.
- Continuous motors and AC/DC, DC/DC converters integrated power electronics. Step down and the step up chopper structures.
- Synchronous motors in servo synchronous machines with Pulse Width Modulator frequency converter.
- Four practical sessions illustrate three kinds of motors and transformer needed in industrial processes.

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
13h45	10h00	26h15	0h00	0h00

In person teaching: 50h00

Taught in English: ⚐⚐⚐ **SD/SR:** 🌍🌍🌍 **Innovation:** ✎✎

Automotive Engineering and Sustainable Mobility (AESM) **1AE04** **Semester 1**

IT: programming

Supervisor: Rachid JENNANE **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Analyze a problem
- Propose an algorithm
- Develop an architecture for a problem
- Use a development environment and a C/C++ compiler

Syllabus

Basics

- Structure of a program in C language
- Basic elements (character, type, constants, variables, blocs, etc.)
- Instructions and Operators
- Conditional structures, iterative structures and connections, etc.
- Pointers and dynamic variables
- Arrays
- Strings
- Functions, passing parameters: by value, by reference and by address

Object oriented programming

- Structure of a program in C++ language
- Classes
- Member variables and member functions
- Specialized constructors
- Overloaded functions and operators
- Data stream
- Abstract class
- Generic classes

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
16h15	0h00	33h45	0h00	0h00

In person teaching: 50h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **1AE05** **Semester 1**

Advanced physics

Supervisor: Azeddine KOURTA **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Understand the inner working of power electronics
- Understand basic automotive aerodynamics
- Solve 1st and 2nd principle based thermodynamic problems

Syllabus

Power electronics

- Semi-conductor physics
- Power MOS
- IGBT

Automotive aerodynamics

- Basics of aerodynamics
- Specificities of automotive aerodynamics
- Wind tunnel experiments

Thermodynamics

- 1st and 2nd principle of thermodynamics
- Ideal gases
- Basic engine cycles

Grading

Written exam, Report

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
32h30	13h45	3h45	0h00	0h00

In person teaching: 50h00

Taught in English: **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **1AE06** **Semester 1**

French culture and language

Supervisor: Geanina BOUTONNE **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Understand spoken french and speak basic sentences.
- Read and write basic french.
- Hold a basic conversation.

Syllabus

- French language sounds
- French grammar
- French conjugation
- Interactive discussions in French

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
0h00	70h00	0h00	0h00	0h00

In person teaching: 70h00

Taught in English: **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **1AE07** **Semester 1**

Vehicle Dynamics 1

Supervisor: Pascal HIGELIN **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Understand vocabulary, technology and general issues and goals of vehicle dynamics applied to passenger cars.
- Choose and model a tire. Design or choose front and rear axles technologies according to an expected behavior. Design suspension systems and anti roll bars.
- Model the behavior of a car using several numerical models, and compare them to real world test measurements.
- Conduct experimental measurements on a real axle or a complete vehicle to obtain the variation of the geometrical characteristics length and angles for roll, pumping and pitching.

Syllabus

- Generalities: SAE Coordinate System. Definition of specific vocabulary. Motion variables. Basic geometry of an Axle (toe, caster, camber, kingpin etc.) and its effect on drivability.
- Tire: Constitution and behavior. Vertical, longitudinal and lateral modelling. Auto- align torque. Pacejka Model and introduction to TM Easy Model.
- Axle: Kinematics modelling of various axle using the theory of the mechanism. Suspension steer and roll properties. Analysis of the design effects on the change of characteristic angles and length (toe, camber etc.) as a function of pumping and rolling. Roll Center of an axle.
- Vertical behavior and suspension design. Spring and shock absorber design for sprung mass, un-sprung mass control in the case of pitching and pumping behavior.
- Transversal Behavior: Ackermann Geometry. Jeantaud's steering system. Bicycle Model. Over steer coefficient, characteristic speed, yaw speed gain. Roll Stiffness of an axle. Roll Flexibility. Lateral Load Transfer. Anti-roll bar design.
- Numerical simulations and comparison to real test results using several models (Simulink, Thesis).
- Practical work 1: Experimental measurements and modeling of the kinematics roll effects on camber and steering angle for the H-Frame axle.
- Practical Work 2: Experimental measurement of suspension steer, roll effect and pitch effect on the geometrical characteristic angles, for a complete car, in case of pure pumping.

Grading

Written exam, Oral exam, Report

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
35h00	22h30	7h30	0h00	0h00

In person teaching: 65h00

Taught in English:⚐⚐⚐ **SD/SR:** 🌍 **Innovation:** ✎✎

Automotive Engineering and Sustainable Mobility (AESM) **1AE08** **Semester 1**

Internal combustion engines

Supervisor: Pascal HIGELIN **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Understand the physical and chemical processes occurring during combustion and scavenging in internal combustion engines. Understand the behavior of an engine when changing its settings using modeling.
- Be able to build an internal combustion engine model. Be able to optimize the size and settings of an engine performance under efficiency, power, emission constraints using modeling.

Syllabus

- Combustion: Thermochemistry and Kinetics applied to combustion. The self-ignition. Premixed flames, flammability limits, flame stability, turbulent combustion. Diffusion flames, biphasic combustion. Internal aerodynamics of an engine. Mixture preparation, requirements of spark ignition and self-ignition, initiation and propagation of combustion (definition of core burning speeds), formation of pollutants. Identification of engine manufacturers needs in terms of fundamentals.
- Thermodynamic models: Classification of thermodynamic models: air cycle models, one and two zone models, multizone models. Combustion chamber walls losses models. Limits of validity.
- Combustion models: semi-empirical combustion models, application to spark ignition engines. Extension to compression ignition engines. Combustion models for spark ignition engines. Combustion models for compression-ignition engines (spray patterns, combustion models in the premix and diffusion phase).
- Scavenging models: filling/emptying models and acoustic 1D intake/exhaust. Boundary conditions: open tubing, closed, partially open junctions. Consideration of thermal losses and friction to the walls. Filling efficiency curves reconstruction.
- Specific Tool: Matlab/Simulink, GTpower, CHEMKIN.

Grading

Written exam, Oral exam, Report

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
16h15	41h15	7h30	0h00	0h00

In person teaching: 65h00

Taught in English: 🏳🏳🏳 **SD/SR:** 🌍🌍🌍 **Innovation:** 🖉🖉

Automotive Engineering and Sustainable Mobility (AESM) **2AE01** **Semester 2**

Acquisition systems and signal processing

Supervisor: Philippe RAVIER **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Mastering Analog to Digital conversion for digital systems
- Mastering the Fourier Transform for spectral analysis of the data
- Selecting and implementing an FIR or IIR filter on a dedicated hardware or software architecture

Syllabus

Signal processing basics

- Analog and digital representation, Shannon theorem
- Time and frequency representation
- Fourier transform
- Noise processing

Digital filtering

- Z transform for digital signals
- Transverse filters
- Recursive filters

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
20h00	20h00	10h00	0h00	0h00

In person teaching: 50h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **2AE02** **Semester 2**

Real Time Programming

Supervisor: Raphaël CANALS **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Mastering techniques for the implementation of digital systems
- Understanding and implementing hardware and software for real-time systems
- Controlling the CAN and FlexRay communication buses

Syllabus

Digital systems

- Number coding and algebra.
- Analog-to-digital and digital-to-analog conversions.

Electronic components

Microcontrollers: applications in automobile.
Microcontrollers: structure and implementation.
Architecture of a microcontroller board.

Role and place of an OS on a processor board.
Architecture of an OS.
Calls to OS functions.

Automotive communication buses

CAN and FlexRay buses architecture.
Communication protocols.

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
17h30	10h00	15h00	3h45	7h30

In person teaching: 50h00

Taught in English: **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **2AE03** **Semester 2**

Control & Simulation of Powertrains

Supervisor: Alain CHARLET **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Understanding why and how hybridization works
- Understanding where energy is lost in a car vs driving conditions
- Being able to build a simple model of a car and its control

Syllabus

Part 1: Control of powertrains

Anti-lock Bracking System (ABS) & Cruise control. This study is performed in simulation with the software Matlab/Simulink.

Part 2: Simulation of powertrains

An overview of electric hybrid powertrains is proposed.
Then, students work on a simulation platform (Simcenter AMESim by Siemens) where they have to build an energy balance of a conventional vehicle.
This study is completed by two practical classes on a rolling test bed where students measure energetic performances of a conventional car vs hybrid car (Toyota Yaris)

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
5h00	22h30	7h30	0h00	0h00

In person teaching: 35h00

Taught in English:🏳🏳🏳 **SD/SR:** 🌍🌍 **Innovation:** 🖉🖉

Automotive Engineering and Sustainable Mobility (AESM) **2AE04** **Semester 2**

Project

Supervisor: Pascal HIGELIN **ECTS: 10**

Skills

At the end of this course, engineering students will be able to:

- Split a complex task into subtasks. Plan and schedule tasks.
- Work as a group. Assign tasks to members of the group taking dependencies into account
- Select the more adequate modeling level and simulation tool
- Present work performed in a concise way focusing on the most important aspects
- Build working powertrain and vehicle dynamics models based on experimental data

Syllabus

- Reformulation of project subject
- Split subject objectives into tasks and sub-tasks
- Schedule tasks and assign them to project members
- Report work performed, current state and upcoming tasks every 2 weeks

Grading

Thesis, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
0h00	0h00	0h00	3h00	130h00

In person teaching: 130h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **2AE05** **Semester 2**

Control and on-board diagnosis applied to ICE

Supervisor: Guillaume COLIN **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Find the good set of parameters for a PID controller on simple systems
- Tune an internal combustion engine control
- Control some simple actuators
- Define, parameterize and implement a simple observer-based diagnosis tool

Syllabus

State of the art of engine control: sensors, actuators

- Gasoline engines
- Diesel engines

Automatic control

- Linear Models (1st order, 2nd order)
- Conventional Linear Control (PID)

Applications to powertrain control: labs

- Experimental engine test benches: tuning and control
- Hardware in the Loop (HIL) & Rapid prototyping for Control: Application on valves

On Board Diagnosis

- Rule based diagnosis
- Observer based diagnosis with numerical simulations on Matlab/Simulink

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
23h45	10h00	16h15	0h00	0h00

In person teaching: 50h00

Taught in English: **SD/SR:** **Innovation:**

Automotive Engineering and Sustainable Mobility (AESM) **2AE06** **Semester 2**

Control and on-board diagnosis applied to vehicle dynamics

Supervisor: Guillaume COLIN **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Find the good set of parameters for a PID controller on simple systems
- Tune a vehicle dynamics control
- Control some simple actuators
- Define, parameterize and implement a simple observer-based diagnosis tool

Syllabus

State of the art

Hardware (sensors, actuators...)
Software

Automatic control

- Linear Models (1st order, 2nd order)
- Conventional Linear Control (PID)

Applications to vehicle dynamics: labs

- Tuning a vehicle dynamics controller
- Hardware in the Loop (HIL) & Rapid prototyping for Control: Application on valves

On Board Diagnosis

- Rule based diagnosis
- Observer based diagnosis with numerical simulations on Matlab/Simulink

Grading

Written exam, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
31h15	8h45	10h00	0h00	0h00

In person teaching: 50h00

Taught in English: ⚐⚐⚐ **SD/SR:** 🌍🌍 **Innovation:** ✎✎

Internet of Things (IoT)

TU Code	Title of the Teaching Unit (TU)	Learning hours	ECTS
Master of Science INTERNET of THINGS (IoT)		**682.0**	***90***
		682.0	***90***
Prerequisites (2 TU among 4)			
IoT01	Mathematics	**40**	***4***
IoT02	IT programming	**40**	***4***
IoT03	Analog and digital electronics	**40**	***4***
IoT04	Web and networks	**40**	***4***
Economy, management and uses			
IoT05	IoT ecosystem	**30**	***4***
Embedded system engineer			
IoT06	Architectures and technologies	**20**	***2***
IoT07	Data transmission	**20**	***2***
IoT08	Design for IoT	**20**	***2***
Full-stack engineer			
IoT09	Servers and frameworks	**20**	***2***
IoT10	Smartphones and tablets	**20**	***2***
IoT11	Cybersecurity	**20**	***2***
Data scientist			
IoT12	Data mining	**20**	***2***
Economy, management and uses			
IoT13	IoT demonstrator	**70**	***6***
Expert approach (1 TU amongst 3)			
IoT14	Embedded systems	**80**	***10***
IoT15	Full-stack integration	**80**	***10***
IoT16	Data Sciences	**80**	***10***
Synthesis project			
IoT17	Final team project	**280**	***18***

Internet of Things **IoT01** **Semester 9**

Mathematics

Supervisor: Carine LUCAS **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Master the different types of signals and their representations
- Master basic transformations and processing of digital signals
- Design filters
- Understand a digital communication chain
- Generate, analyze, process, detect digital signals with Matlabsignal

Syllabus

- Elementary descriptive statistics: bar charts, histograms, quantiles, box plots, conditional diagrams, contingency diagrams.
- Optimization: gradient descent, application to linear regression, projected gradient descent.
- Modeling: Bayes model, variational formulation. Application to reconstruction and regulation.
- Fourier analysis: notes on Hilbert space, complex exponentials, discrete Fourier transform, discrete Fourier series, properties, amplitude and phase spectrum, timefrequency analysis and spectrogram, fast Fourier transform.
- Filtering: time-invariant linear systems, convolution operator, impulse response, frequency response, ideal filters.
- Random signals: random vectors and processes, spectral representation, power spectral density, white noise, ARMA processes.
- The courses will be accompanied by computer works during which we will use the softwares R, Python, Matlab

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
20h00	0h00	20h00	0h00	0h00

In person teaching: 40h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Internet of Things **IoT02** **Semester 9**

IT programming

Supervisor: Rachid JENNANE **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Analyze a problem
- Develop programs in the Python language
- Propose an application under the C language

Syllabus

Python

- Basic types and operations
- Control structures
- Functions
- Files
- Classes, inheritance
- Modules

C Language

- Types, variables, control instructions
- Functions, parameter passing
- Dynamic variables
- Single and multi-dimensional automatic/dynamic arrays
- Strings of characters
- Structures
- Stream

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
10h00	0h00	30h00	0h00	0h00

In person teaching: 40h00

Taught in English: **SD/SR:** **Innovation:**

Internet of Things **IoT03** **Semester 9**

Analog and digital electronics

Supervisor: Rodolphe WEBER **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Understand the operation of a simple electronic circuit based on passive components
- Analyze a single electrical circuit in DC, AC or transient mode
- Understand the notions of combinatorial and sequential logic in digital electronics
- Build a simple system based on a microcontroller

Syllabus

Analog electronics

- Instrumentation
- Metrology
- Impedance adaptation
- Continuous and transient linear circuits
- Kirchoff's Laws. Theorem of Thevenin, of Norton...
  Operational amplifier, diode, bipolar transistor

Digital electronics

- Combinatorial logic
- Sequential logic

Signal shaping before processing

- Filtering
- Amplification / leveling

Practicum

- Applications

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
12h30	8h45	18h45	3h45	0h00

In person teaching: 40h00

Taught in English: 🏳🏳🏳 **SD/SR:** **Innovation:**

Internet of Things **Iot04** **Semester 9**

Web and networks

Supervisor: Raphaël CANALS **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Understand the basics of Ethernet and TCP/IP networks and the different physical media (fibre, Wifi, Ethernet, PLC, etc.) involved
- Know how to set up and parameterize a network and routes, perform elementary calculations (classes, ranges in IPv4 and IPv6)
- Observe and interpret frames circulating on a network

Syllabus

Networks

- Network fundamentals: OSI layered model, Ethernet and TCP/IP, physical media ARP, routes, IPv4, IPv6, DNS
- TCP/UDP, DHCP: TCP reliability (3 Way Hand-Shake, etc.), congestion management
- Headers, Checksums, state diagram, netsat
- UDP: differences and uses
- DHCP - NAT and PAT

Web

- Setup of a static site with HTML5 and CSS
- Dynamic programming with a Python microframework: Flask
- Project structure, templates
- Use of databases
- API Consumption – JavaScript

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
10h00	17h30	12h30	0h00	0h00

In person teaching: 40h00

Taught in English: 🏳🏳🏳 **SD/SR:** **Innovation:**

Internet of Things **IoT05** **Semester 9**

IoT ecosystem

Supervisor: Raphaël CANALS **ECTS: 4**

Skills

At the end of this course, engineering students will be able to:

- Have a global and transversal vision of the social economic aspects related to the development and deployment of an IoT solution
- Understand the design and development of an IoT solution with an iterative approach and a user service-oriented approach

Syllabus

Markets, economic issues and business intelligence

- IoT value chain (actors, positions and issues)
- Objects, data, services and value creation (challenges, barriers, business models)
- Fields of application, market developments and expectations related to mobility

Standards, regulations, industrial property

- Norms and standards: foundations, procedures and organizations
- Intellectual property, industrial property and strategies (secrets vs. patents)
- Social and legal aspects, personal data and digital identities

Design of services, of objects and industrialization

- Functional analysis, life cycle and solution development
- Service design (utility, employability, usability and users paths experiences)
- Scale-up, industrialization, deployment of IoT solutions, supply chains and costs

Management of digital projects, innovative entrepreneurship

- Agile methods for management and business administration
- Innovative entrepreneurship and Lean Startup approach)
- Business plans and fundings of innovative projects

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
16h15	7h30	6h15	0h00	0h00

In person teaching: 30h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Internet of Things **IoT06** **Semester 9**

Architectures and technologies

Supervisor: Raphaël CANALS **ECTS: 2**

Skills

At the end of this course, engineering students will be able to:

- Understand how a processor architecture works
- Choose a hardware architecture
- Understand the advantages of integration: consumption, dimensions, reliability, ...
- Realize the acquisition of a sensor data
- Manage asynchronous events
  Implement a serial communication

Syllabus

Processor system architectures

- Different processor families
- Architecture of a processor board
- Program memory, data memory and input/output devices

Microcontroller architectures

- ARM processor architecture: RISC architecture, operation, pipeline, operating modes
- Interruption: role, asynchronism, management, multitasking, ...
- Timers, meters and PWM
- Development tools and environments
- Understanding of the high-level language to machine code compilation chain

Communicating systems

- Different types of serial link, implementation

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
7h30	0h00	12h30	0h00	0h00

In person teaching: 20h00

Taught in English: **SD/SR:** **Innovation:**

Internet of Things **IoT07** **Semester 9**

Data transmission

Supervisor: Rodolphe WEBER **ECTS: 2**

Skills

At the end of this course, engineering students will be able to:

- Choose a wired or radio transmission protocol depending on the constraints (data rate, latency, power consumption, transmission range, bit error rate, regulations and standards, EMC...)
- Understand the architecture of a digital radio transmission system
- Understand the basics of antenna design and antenna impedance adaptation
- Assess a link budget
- Know the certification procedure for IoT systems

Syllabus

Introduction to digital communication

- The overall architecture and associated parameters (source, channel, bandwidth, data rate, signal to noise ratio, bit error rate) ; Linear and non-linear digital modulations and associated parameters (inter symbol interferences, spectral efficiency, pulse shaping, bit error rate, Eb/No) ; Software defined radio (SDR) architecture and et associated tools (eye diagram, constellation, carrier and symbol synchronization) ; Demultiplexing techniques OFDM, FDMA, TDMA, CDMA ;
- Implementation on a SDR GnuRadio demonstration board

RF considerations

- Antenna characteristics (gain, directivity, VSWR, …) ; Antenna design and antenna adaptation issues ; The certification procedure for IoT systems ; Measurement tools for antenna and EMC studies, Link budget

Standard radio communication protocol

- Short range (WPAN, WLAN): BT, BLE, Wi-Fi, ZigBee, Thread, Z-Wave, RFID, NFC, EnOCEAN, Ant+ ; Long range (WNAN, WWAN, LPWAN): ZigBee-NAN, WirelessHART, Wi-SUN, 4G/5G, LTE-M, Sigfox, Lora, 6LoWPan, NB-IoT, Telensa … ; Standardization, industrial alliances

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
15h00	2h30	2h30	10h00	0h00

In person teaching: 20h00

Taught in English: ⚐⚐⚐ **SD/SR:** **Innovation:** 🖉🖉

Internet of Things **IoT08** **Semester 9**

Design for IoT

Supervisor: Caroline Zahnd **ECTS: 2**

Skills

At the end of this course, engineering students will be able to:

- Understand the processes for designing connected and interactive objects (methodology, tools, specificities)
- Address the issue interfaces (HMI, UI design, physical interfaces in connected objects, ...)
- Understand the concepts of Interaction design and user experience (UX design)
- Master the bases of a design culture (nature of the business approach, historical perspectives, then more specifically culture and history of the design of technological objects, then of connected objects, references to be known, designers and flagship projects

Syllabus

Introduction to design

- Design of connected and interactive objects (methodology, tools, specificities)
- Interface design (HMI, physical interfaces in connected objects...)
- Interaction design and user experience (UX design, conceiving the nature of interaction as an object of the design process)

Design in practice

- Analysis of the context of use and needs
- Research and contribution of design references and monitoring of the existing and research of visual inspirations
- Usage scenario, user experience reflection (UX)
- Object design concept
- Interaction design concept (GUI, user experience)
- Form, materials and plastic qualities
- Implementation and prototyping

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
20h00	0h00	0h00	47h30	0h00

In person teaching: 20h00

Taught in English: 🏳🏳🏳 **SD/SR:** **Innovation:**

Internet of Things **IoT09** **Semester 9**

Servers and frameworks

Supervisor: Matthieu EXBRAYAT **ECTS: 2**

Skills

At the end of this course, engineering students will be able to:

- Design and implement a REST web service to collect and transmit data in connection with an existing relational or NOSQL database
- Propose a client/server architecture with possibly several services to answer a problem
- Test and secure this API
- Implement a Python framework to develop this type of service

Syllabus

- http protocols - REST architectures
- Client/Server
- Address an API design framework
- Introduction to REST Web Services – Design, request and authentication
- API testing tools
- Notions about microservices

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
20h00	0h00	0h00	20h00	0h00

In person teaching: 20h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:** ✎✎

Internet of Things **IoT10** **Semester 9**

Smartphones and tablets

Supervisor: Aladine CHETOUANI **ECTS: 2**

Skills

At the end of this course, engineering students will be able to:

- Develop applications on Android and iOS
- Manage the packaging of activities
- Communicate between activities and transmit data
- Use the different existing data sensors (accelerometer, gyroscope, camera, audio, GPS, ...)
- Use communication channels (bluetooth, Wifi)
- Transmit data between smartphones

Syllabus

Java & Swift

- Introduction to JAVA (Android) and SWIFT (iOS) programming ; Program Development

Android

- Interface management (design and XML) ; Basic "Hello Word" application; Multi-activity application ; Control management ; Transfer of information ; Use of sensors ; Communication

iOS

- Interface management (design) ; Basic "Hello Word" application ; Multi-window application ; Control management ; Transfer of information ; Use of sensors ; Communication

Complements

- Cross-platform ; PWA (Progressive Web Apps): nomadic continuous access to information without reliable connection

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
5h00	0h00	15h00	0h00	0h00

In person teaching: 20h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Internet of Things **IoT11** **Semester 9**

Cybersecurity

Supervisor: Laurent MOULIN **ECTS: 2**

Skills

At the end of this course, engineering students will be able to:

- Understanding the fundamentals of cyber security

Syllabus

- The basics of cyber security
- Implementing secure chat
- Creating ransomware
- Participating in a capture flag

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
20h00	0h00	0h00	7h30	0h00

In person teaching: 20h00

Taught in English: 🏳🏳🏳 **SD/SR:** 🌍 **Innovation:** ✎✎

Internet of Things **IoT12** **Semester 9**

Data mining

Supervisor: Frédéric ROS **ECTS: 2**

Skills

At the end of this course, engineering students will be able to:

- Use statistical data analysis tools such as linear or logistic regression, PCA and factor analysis
- Use data visualization or representation tools in MATLAB or R languages
- Use tools for pre-processing data and extracting characteristic attributes from the data
- Understand the principes and use basic classification methods such as SVM and neural networks

Syllabus

Analysis tools

- Linear and logistic regression
- Principal Component Analysis (PCA)
- Factor analyses

Time series

Data mining and visualization

- R language (introduction) and descriptive graphs
- Practicum in multimedia data analysis (images and audio) using R and/or Python

Data pre-processing and attribute extraction

- Some data denoising techniques
- Characteristic attributes: audio and image examples
- Attribute selection

Classification methods

- SVM Method
- Classification by neural networks
- Introduction to Deep Learning

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
11h15	3h45	5h00	0h00	0h00

In person teaching: 20h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Internet of Things **IoT13** **Semester 9**

IoT demonstrator

Supervisor: Rodolphe WEBER **ECTS: 5**

Skills

At the end of this course, engineering students will be able to:

- Better understand and assimilate the entire chain, from the sensor to the Data Sciences
- Realize a functional IoT demonstrator, from end to end of the chain

Syllabus

- Thanks to the System Approach formation, each participant realizes in team an industrial project which consists in:
  - Realizing, testing, developing or optimizing a communicating system around a server base on which a management of data stored in a base is carried out
  - Proposing objectives and a work plan for possible successors.
- During this project, the student benefits from the supervision of a scientific leader or supervisor, whom he or she must meet at least once a week to report on the work carried out and the actions to be implemented. At the end of the project, an oral presentation of the work is organised followed by a demonstration and a written report must be given to the supervisor.

Grading

Oral exam, Report

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
17h30	3h45	18h45	56h15	30h00

In person teaching: 70h00

Taught in English: **SD/SR:** **Innovation:**

Internet of Things **IoT15** **Semester 9**

Full-stack integration

Supervisor: Raphaël CANALS **ECTS: 8**

Skills

At the end of this course, engineering students will be able to:

Knowledge and understanding of:

- Technologies involved in end-to-end IoT solutions. Protocols for local & global connectivity
- The architecture and concept of different cloud models: IaaS, PaaS, SaaS, cloud virtualization, cloud storage, data management
- The decisive factors for the user interaction in the context of the Internet of Things (IoT)

Practical skills:

- The student can design the architecture and technologies needed to implement IoT devices
- Design usable functional prototypes of interactive system
- Create application by utilizing cloud platforms

Syllabus

- **Device hardware:** IoT objects (sensors, actuators, smartphones, gateways)
- **Device software**: Embedded / firmware programming, edge operating systems and applications
- **Communications**: Models, data exchange formats, protocols (MQTT, CoAP, HTTP REST, ...)
- **Cloud Platform & Middleware Programming:** Delivery models – IaaS, PaaS, SaaS, cloud platform ; micro-services using Docker
- **Security and regulations:**
  - IoT security standard: identity, authentication, authorization, confidentiality, integrity, availability, lifecycle management (OTA upgrades)
  - GDPR, ePrivacy regulation, privacy by design. Practical cryptography for the Internet of Things
- **Scalability and Management:** (devices, applications, network): IoT interoperability and scalability.
- **Integration with IT & other systems:** Open data management & API. Aggregations.
- **Laboratory and project:** Case studies: Smart homes/buildings, smart cities, smart industry, smart medical care. Human activity recognition. Air quality analysis, industrial internet (IoT)

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
20h00	30h00	30h00	21h15	0h00

In person teaching: 80h00

Taught in English:🏳🏳🏳 **SD/SR:** 🌍 **Innovation:**

Internet of Things **IoT16** **Semester 9**

Data Sciences

Supervisor: Bruno GALERNE **ECTS: 8**

Skills

At the end of this course, engineering students will be able to:

- Choose and implement methods adapted to the types of data involved
- Anticipate high-performance and/or distributed computing needs

Syllabus

Classical multivariate analyses: PCA, CFA, ACM

Learning and classification methods

- Classical unsupervised methods (kmeans, CAH) towards model-based classification (= multidim Gaussian/nonparametric and EM mixing) ; Supervised methods: logistic regression, CART, random forest (boosting and bagging), discriminant analysis ; Clustering of symbolic data and search for frequent patterns

Image processing

- Analysis, Segmentation, Denoising, Classification, Local descriptors and texture analysis, Variational methods, convex optimization and neural networks

Big data

- Initiation to the Hadoop/MapReduce paradigm, scaling up statistical tools for distributed data, Rhadoop tool,
- noSQL, Hadoop/MapReduce, HIVE, Hbase, heterogeneous data

HPC

- Parallel calculation with R ; GPGPU (CUDA) ; Open MP, MPI, ...

New technologies under R

- Reproducible and interactive documents: RMarkdown, Shiny, Rdashboard

Grading

Written exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
40h00	0h00	40h00	0h00	0h00

In person teaching: 80h00

Taught in English:⚐⚐⚐ **SD/SR:** **Innovation:**

Internet of Things **IoT17** **Semester 9**

Final team project

Supervisor: Raphaël CANALS **ECTS: 17**

Skills

At the end of this course, engineering students will be able to:

- Design, test a system or develop a process following a quality approach in accordance with industrial standards, favouring both methodological project management (specifications writing, time management by defining the various tasks to be carried out) and the effective completion of the work required

Syllabus

- During a fixed period of eight weeks, each student works in teams on an industrial project consisting of:

  - Designing, testing, developing or optimising an industrial process or a software system which meets precise specifications defined beforehand by the scientific manager or project supervisor in collaboration with the company applying for the project (or the laboratory).
  - Proposing objectives and a work plan for possible successors.

- During this project, the student benefits from the coaching of a scientific manager or project supervisor whom he must meet at least once a week to report on the work carried out and the actions to be implemented. At the end of the project, an oral presentation of the work is organised followed by a demonstration and a written report must be given to the supervisor

Grading

Thesis, Oral exam

Learning hours

Lectures	Tutorials	Lab sessions	Free labs	Project
1h15	0h00	0h00	17h30	8h00

In person teaching: 9h15

Taught in English: 🏳🏳🏳 **SD/SR:** **Innovation:** 🖉🖉

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