Ecole Nationale Supérieure de Mécanique et d'Aérotechnique

POITIERS - FUTUROSCOPE

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Master of Science In Aeronautics & Space

Aeronautical Mechanics and Energetics (AME)

Course Catalogue

2018-2019

Table of contents

YEAR 1

SEMESTER 1 - COMMON PART				
Teaching Unit	**Course title**	**Hours**	**ECTS Credits**	**Page**
UE1-1	Thermochemistry	11h00	3	7
	Propulsion 1	13h45	3	8
UE1-2	Basics of thermal sciences	30h00	4.5	9
	Numerical methods	39h00	5	11
UE1-3	Flight mechanics	20h00	3.5	12
	Structural mechanics	35h45	5	10
UE1-4	French as a foreign language (FLE)	45h00	3	5
	French culture	42h00	3	6

SEMESTER 2 - MAJOR: ENERGETICS AND PROPULSION (EPROP)				
Teaching Unit	**Course title**	**Hours**	**ECTS Credits**	**Page**
UE2-1e	Fluid mechanics	39h00	5	15
	Gas dynamics	38h15	5	16
UE2-2e	Propulsion 2	45h00	5	17
	Metrology	8h45	1	18
UE2-3	French as a foreign language (FLE)	36h00	3	13
	French culture	33h00	3	14
UE2-4	Project	270h00	8	23

SEMESTER 2 - MAJOR: HIGH TEMPERATURE MATERIALS (HTM)				
Teaching Unit	**Course title**	**Hours**	**ECTS Credits**	**Page**
UE2-1h	Materials science	38h15	5	21
	Structures/Materials Project	18h00	4.5	20
UE2-2h	Vibrations – Finite Element	42h30	5	19
	Helicopters	12h30	1.5	22
UE2-3	French as a foreign language (FLE)	36h00	3	13
	French culture	33h00	3	14
UE2-4	Project	270h00	8	23

YEAR 2

SEMESTER 3 - MAJOR 1: ENERGETICS AND PROPULSION (EPROP)				
Teaching Unit	**Courses title**	**Hours**	**ECTS Credits**	**Page**
UE3-1e	Turbulence	30h00	2.5	26
	Combustion	38h45	2.5	27
	Turbulent combustion	15h00	1.5	30
UE3-2e	Atomisation Two Phase flow	15h00	1.5	28
	Two-phase combustion	15h00	1.5	29
	Radiation in semi-transparent environment	25h00	2	33
	New combustion mode for propulsion	16h45	2	35
UE3-3e	Turbulent heat exchange	20h00	1	34
	Turbomachinery	25h00	2	31
	Rocket propulsion	15h00	1.5	32
	Numerical combustion for engines	32h00	2	36
UE3-4e	French as a foreign language (FLE)	21h00	1.5	24
	French culture	21h00	1,5	25
	Project	120h00	7	49

SEMESTER 3 - MAJOR 2: HIGH TEMPERATURE MATERIALS (HTM)				
Teaching Unit	**Courses title**	**Hours**	**ECTS Credits**	**Page**
UE3-1h	Finite Elements modelling	30h00	2.5	37
	Plasticity-Viscoplasticity	30h00	2.5	38
	High Temperature Alloys	15h00	2	43
UE3-2h	Fracture mechanics	12h30	1	40
	Atomic diffusion and applications	18h45	2	42
	Corrosion of engineering materials	12h30	1	47
	Creep	12h30	1	48
	Fatigue	15h00	1	41
UE3-3h	Thermal Barrier Coatings for Gas Turbine Engine	12h00	1	44
	Materials processing	24h00	2	45
	Engineering Failure Analysis	6h00	1.5	46
	Materials mechanical properties	30h00	2.5	39
UE3-4h	French as a foreign language (FLE)	21h00	1,5	24
	French culture	21h00	1,5	25
	Project	120h00	7	49

SEMESTER 4 FINAL PROJECT				
Teaching Unit	**Courses title**	**Duration**	**ECTS Credits**	**Page**
	Master thesis	6 months	30	50

Teaching departments

-MFA : Mécanique des Fluides et Aérodynamique / *Fluid mechanics & Aerodynamics*
-MSISI : Matériaux, Structures et Ingenierie des Systèmes Industriels / *Materials, Structures, Industrial Systems Engineering*
-ET : Energétique et Thermique / *Energetics & Heat Transfer*
-IA: Informatique et Automatique / *Computer Science & Automatics*
-FGH : Formation Générale et Humaine / *General Studies*

Semester 1

French as a foreign language (FLE)			
Course code: AFL1		**ECTS Credits: 3**	
Department	: FGH	**Lectures**	: 45h
Lecturers	: C Maissin	**Tutorials**	:
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 1st semester	**Project**	:
Assessment method(s)	: written tests + continuous assessment	**Home works**	:
Language of instruction	: French	**Total hours**	: 45h
Type of courses	: Compulsory		

LEVEL 1 (A1 - BREAKTHROUGH)

Prerequisites: None

Objectives:
• Being able to understand a conversation, full sentences and basic information about everyday life.
• Being able to answer basic questions and describe one's everyday life environment with basic vocabulary.
• Being able to fill up a form, to write a short message or a letter in order to get basic information.

Content:
• Courses are based on the CEFRL (Common European Framework of Reference for Languages).
• Use of communicative approach to language acquisition based on a textbook, various semi-authentic oral and written documents...
• Special emphasis on oral comprehension and expression.

Communicative themes:
Module 1: Talking about yourself
Module 2: Exchange
Module 3: Working in Space
Module 4: Lying in time

Recommended reading:
- Watching French TV,
- Listening to French radio,
- Reading French newspapers,

Web sites: www.lepointdufle.fr; www.fle.fr…

French culture

Course code: AFC1		ECTS Credits: 3	
Department	: FGH	**Lectures**	: 42h00
Lecturers	: J.Rouet	**Tutorials**	:
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 1st semester	**Project**	:
Assessment method(s)	: written tests + continuous assessment	**Home works**	:
Language of instruction	: French	**Total hours**	: 42h00
Type of courses	: Compulsory		

Objective: Provide French culture understanding

Prerequisites: None

Content:
Completing the non-French speaking students' academic background in order to enable them to:

- Understand their counterparts in different situations
- Be able to communicate in everyday French language
- Get a better approach into French culture and help them carve out a place into French society during their studies

Listening comprehension, speaking, reading comprehension and writing through videos and recordings. Studying French culture and today's French Society.

Recommended reading: None

Thermochemistry

Course code: ATH1		ECTS Credits: 3	
Department	: ET	**Lectures**	: 2h30
Lecturers	: Z.Bouali	**Tutorials**	: 2h30
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 1st semester	**Project**	: 6h00
Assessment method(s)	: 1 project	**Home works**	:
Language of instruction	: English	**Total hours**	: 11h00
Type of courses	: Compulsory		

Objective: Handling of the main tools for future applications to propulsive systems

Prerequisites: Basics of thermodynamics (systems, principles)

Content:

Thermodynamics of reactive systems

- Properties of reactive mixture
- Characteristics of combustion products, Flame temperature
- Effects of input parameters on combustion performance
- Application of H_2-O_2 and C_3H_8-Air mixtures

Recommended reading:

L. Borel, *Thermodynamique et énergétique*, Presses polytechniques, Lausanne, CH
K.E. Bett, J.S. Rowlinson, G. Saville, *Thermodynamics for chemical engineers*, The Athlone Press, London, UK
P. Bauer, *Aerothermochimie - Propulseurs Aéronautiques et Spatiaux*, Ed. Ellipses, France
P. Bauer, C. Cheze, *La thermodynamique, des principes aux applications*, Ed. Ellipses, France

BACK

Propulsion 1

Course code: APP1 — ECTS Credits: 3

Department	: ET	**Lectures**	: 7h30
Lecturers	: C.Strozzi	**Tutorials**	: 6h15
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 1st semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 13h45
Type of courses	: Compulsory		

Objective: Introduction to basic knowledge of propulsion

Prerequisites: Basic thermodynamics of open and closed systems

Content:

1. **Introduction to the general concept of propulsion**
2. **Airbreathing propulsive systems (ideal cycles)**
   - Calculation procedure
   - Application to ramjet engine
   - Application to turbojet engine
3. **Rocket propulsion: solid propellant systems**

Recommended reading: P. Bauer, *Aerothermochimie - Propulseurs Aéronautiques et Spatiaux*, Ed. Ellipses, France

BACK

Basics of thermal sciences

Course code: ABT1		ECTS Credits: 4.5	
Department	: ET	**Lectures**	: 20h00
Lecturers	: D. Saury	**Tutorials**	: 10h00
Year of study	: 1st year	**Laboratory sessions.**	:
Semester	: 1st semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 30h00
Type of courses	: Compulsory		

Objective: To introduce the main concepts of heat transfer and to understand different transfer methods (physical aspects, energetic balances, calculation principle of temperature fields)

Prerequisites: none

Content:

1. Overview : the main heat transfer modes (conduction, convection & radiation)
2. Fundamental of heat
   - Phenomenology of conduction
   - General equations of conduction
   - Steady state problems
   - Transient and periodic regimes
3. Fundamental of Convection
   - Phenomenology of convection
   - General equations of convection
   - Similarity and dimensional analysis
   - Forced convection in external flow, internal flow
   - Natural convection
   - Mixed Convection
4. Fundamental of Radiation
   - Basic laws and quantities
   - Black body radiation
   - Actual surfaces and emission factors
   - View Factors
   - Radiative transfer between surfaces
5. Introduction to mass transfer

Recommended reading : none

BACK

Structural mechanics

Course code: ASM1		ECTS Credits: 5	
Department	: MSISI	**Lectures**	: 12h30
Lecturers	: L. Signor, C.Nadot, O.Smerdova	**Tutorials**	: 11h15
Year of study	: 1st year	**Laboratory sessions**	: 12h00
Semester	: 1st semester	**Project**	:
Assessment method(s)	: 1 written exam, 1 practical work test	**Home works**	:
Language of instruction	: English	**Total hours**	: 35h45
Type of courses	: Compulsory		

Objective: Study and design of structures composed of beams. Introduction to advanced problems (plates, non-linear behavior, instability...)

Prerequisites: Solid Mechanics / Elasticity (MSO1), Strength of Materials / Beam theory (RDM2)

Content:

1. **Introduction**
   - Motivation and objectives
   - Prerequisites in elasticity
   - Prerequisites in beam theory
2. **Beam theory - Complements**
   - Trusses
   - Composite beams
3. **Energy methods & statically indeterminate problems**
   - Introduction
   - Castigliano's theorem
   - Menabrea's theorem
   - Statically indeterminate problems
4. **Buckling**
   - Introduction and definitions
   - Determination of Euler buckling force
   - Energy methods
   - Lateral buckling & snap-through
5. **Study of thin wall sections**
   - Introduction
   - Shear stress in bending
   - Shear stress in torsion
6. **Introduction to elasto-plasticity**
   - Mechanical behaviour of materials, tensile test
   - Failure and yield criteria (Rankine,Von Mises, Tresca)
   - Bending of elastic-plastic beams
   - Limit load, plastic hinge
7. **Plate theory**
   - Equilibrium equations
   - Kirchhoff's theory

Recommended reading: None

BACK

Numerical methods

Course code: ANM1		ECTS Credits: 5	
Department	: MFA/ ET	**Lectures**	: 7h30
Lecturers	: A. Benselama; G.Lehnasch, F.Virot	**Tutorials**	: 7h30
Year of study	: 1st year	**Laboratory sessions**	: 15h00
Semester	: 1st semester	**Project**	: 9h00
Assessment method(s)	: 1 written test, 1 practical work test, 1 project	**Home works**	:
		Total hours	: 39h00
Language of instruction	: English		
Type of course	: Compulsory		

Objective: get an overview of resolution methods for partial differential equations that model mechanical problems (in fluid mechanics, heat transfer and structural calculation, for instance)

Prerequisites: basic numerical analysis: numerical integration and derivation; resolution of ordinary differential equations; programing language: FORTRAN, C or C++

Content:

1. Introduction to computational physics

2. Classification of Partial Differential Equation
- Generic examples: Poisson, heat, wave equations
- Classification by characteristics: hyperbolicity, parabolicity and ellipticity

3. An overview of solution strategies
- Equations to be solved
- The general form of the conservative equations: the transport equation
- Lax(-Richtmyer) theorem

4. Space and time discretization
- Nodal approximation of functions
- Weighted residual methods (WRM)
- Finite Difference Method: consistance, accuracy and energy conservation
- Finite Element Method–Galerkin method and skewing
- Finite Volume Method
- Time discretization: finite-difference-like and quadrature methods
- Stability: matrix spectrum and von Neumann analyses

5. Equations of motion
- two-dimensional problem of an incompressible flow
- Domain discretization: collocation and staggered grid schemes
- Velocity-pressure coupling methods: pressure correction and pressure equation techniques

6. Boundary Element method
- Adjoining problem and Green identities
- the reciprocity relation
- discretization

Recommended reading:

Roache, P.J., Fundamentals of computational fluid dynamics, Hermosa Pub, 1998Hirsch, C., Numerical computation of internal and external flows, volume 1: Fundamentals of numerical discretization, John Wiley and Sons, Ltd., 1988 Patankar, S. V., Numerical heat transfer and fluid flow, Hemisphere, 1980 Strang, G. and Fix, G., An analysis of the finite element method, Prentice Hall, 1973 Tannehill, J. C. *et al.*, Computational fluid mechanics and heat transfer, Taylor and Francis, 1997

BACK

Flight mechanics

Course code: AFM1 — ECTS Credits: 3.5

Department	: MFA	**Lectures**	: 11h15
Lecturers	: A.Spohn	**Tutorials**	: 8h45
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 1st semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
		Total hours	: 20h00
Language of instruction	: English		
Type of courses	: Compulsory		

Objective: Basic concepts of flight mechanics

Prerequisites: None

Content:

- The atmosphere
- Geometrical and mechanical modelling of the airplane
- Basic concepts of aerodynamics
- Flight equations
- Airplane performance and flight domain
- Longitudinal stability – Eigen modes

Lab works sessions (2): Initial scaling of a light aircraft

Recommended reading: None

French as a foreign language (FLE)			
Course code: AFL2		**ECTS Credits: 3**	
Department	: FGH	**Lectures**	: 36h00
Lecturers	: C Maissin	**Tutorials**	:
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 2nd semester	**Project**	:
Assessment method(s)	: written tests + continuous assessment	**Home works**	:
		Total hours	: 36h00
Language of instruction	: French		
Type of courses	: Compulsory		

LEVEL 1 (A1 - BREAKTHROUGH)

Prerequisites: None

Objectives:
• Being able to understand a conversation, full sentences and basic information about everyday life.
• Being able to answer basic questions and describe one's everyday life environment with basic vocabulary.
• Being able to fill up a form, to write a short message or a letter in order to get basic information.

Content:
• Courses are based on the CEFRL (Common European Framework of Reference for Languages).
• Use of communicative approach to language acquisition based on a textbook, various semi-authentic oral and written documents...
• Special emphasis on oral comprehension and expression.

Communicative themes :
Module 1: Talking about yourself
Module 2: Exchange
Module 3: Working in Space
Module 4: Lying in time

Recommended reading:
- Watching French TV,
- Listening to French radio,
- Reading French newspapers,

Web sites: www.lepointdufle.fr; www.fle.fr…

French culture

Course code: AFC2

ECTS Credits: 3

Department	: FGH	**Lectures**	: 33h00
Lecturers	: J.Rouet	**Tutorials**	:
Year of study	: 1st year	**Laboratory sessions** .	:
Semester	: 2nd semester	**Project**	:
Assessment method(s)	: written tests + continuous assessment	**Home works**	:
		Total hours	: 33h00
Language of instruction	: French		
Type of courses	: Compulsory		

Objective: Provide French culture understanding

Prerequisites: None

Content:
Completing the non-French speaking students' academic background in order to enable them to:

- Understand their counterparts in different situations
- Be able to communicate in everyday French language
- Get a better approach into French culture and help them carve out a place into French society during their studies

Listening comprehension, speaking, reading comprehension and writing through videos and recordings. Studying French culture and today's French Society.

Recommended reading: None

Semester 2
Major: Energetics and Propulsion (EPROP)

Fluid mechanics			
Course code: AFM2		**ECTS Credits: 5**	
Department	: MFA	**Lectures**	: 15h00
Lecturers	: M.Meldi	**Tutorials**	: 15h00
Year of study	: 1st year	**Laboratory sessions**	: 09h00
Semester	: 2nd semester	**Project**	:
Assessment method(s	: 1 written test, 1 practical work test	**Home works**	:
Language of instruction	: English	**Total hours**	: 39h00
Type of courses	: Compulsory		

Objective: To give the students not only a basic technical background but also physical and phenomenological bases that will enable them to handle complex problems.

Prerequisites: Basic fluid dynamics

Content:

1. **Physical mechanisms and flow models**
   - Description of a fluid
   - Balance equations
   - Models of flow motion
2. **Incompressible viscous flows**
   - Important physical properties
   - Characteristic scales
   - Examples of exact solutions
   - Elementary notions of flow stability analysis
3. **Laminar boundary-layer**
   - Localisation of viscous effects in High Reynolds number flows
   - Boundary layer characteristic parameters
   - Prandtl equations;
   - Integral balance: Von Karman equation
   - Boundary layer on a flat plate
   - Effect of a pressure gradient
   - Flow separation and its consequences
4. **Turbulent flows, an introduction**
   - Mean flow equations
   - Physical consequences of turbulent agitation
   - Concept of turbulent diffusivity; near wall flows
5. **Compressible flow of a perfect fluid**
   - Introduction
   - Description of compressible and inviscid flows
   - Stagnation quantities
   - Steady one-dimensional compressible flow

Recommended reading:

H. Oertel, *Prandtl's essentials of fluid mechanics*, Springer, 2003
D.J. Tritton, *Physical fluid dynamics*, Oxford Science Publications, 1998

BACK

Gas dynamics

Course code: AGD2 — ECTS Credits: 5

Department	: MFA	**Lectures**	: 12h30
Lecturers	: E. Goncalvès	**Tutorials**	: 13h45
Year of study	: 1st year	**Laboratory session**	: 12h00
Semester	: 2nd semester	**Project**	:
Assessment method(s)	: 1 written test, 1 practical work test	**Home works**	:
Language of instruction	: English	**Total hours**	: 38h25
Type of courses	: Compulsory		

Objective: Understanding of the physics of shock waves and expansion waves. Application to internal aerodynamics

Prerequisites: Basic fluid mechanics, with isenropic compressible flows. Basic knowlegde on hyperbolic PDE's and systems

Content:

1. **Shock waves**
   - Jump relations
   - Normal shock wave
   - Oblique shock wave
2. **One-dimensional unsteady compressible flows**
   - Cauchy problem
   - Method of characteristics
   - Simple-wave flows
   - Shock formation
3. **Two-dimensional stationary supersonic flows**
   - Method of characteristics
   - Simple-wave flows
   - Prandtl-Meyer expansion
4. **Air intakes**
   - Critical and supercritical regimes
   - Adaptation
   - Head losses in subsonic flow
5. **Supersonic nozzles**
   - Boundary layer and displacement effect
   - Flow rate and thrust
   - Adaptation and separation

Recommended reading:

J.D. Anderson Jr., *Modern compressible flow: with historical perspective*, McGraw Hill, 2002
S. Candel., *Mécanique des fluides*, Dunod, 1995
I. Ryhming, *Dynamique des fluides*, Presses Polytechniques et Universitaires Romandes, 2004 (3e edition)

BACK

Propulsion 2

Course code: APP2		ECTS Credits: 5	
Department	: ET	**Lectures**	: 19h30
Lecturers	: M. Bellenoue	**Tutorials**	: 7h30
Year of study	: 1st year	**Laboratory sessions**	: 3h00
Semester	: 2nd semester	**Project**	: 15h00
Assessment method(s)	: 2 written tests, 1 practical work test, 1 project	**Home works**	:
		Total hours	: 45h00
Language of instruction	: English		
Type of courses	: Compulsory		

Objective: Deepening course on propulsive systems.

Prerequisites: Basic knowledge on propulsion systems thermodynamics

Content:

- **Introduction and background**
- **Air-breathing propulsion**
  - Gas turbine engines
  - Turbojets
  - Non conventional air breathing engines (ramjet, turbo-ramjet, pulse detonation engine)
- **Rocket engine**
  - Generalities on rocket engines
  - Liquid propellant rocket engines
  - Solid propellant rocket engines

Recommended reading: None

BACK

Metrology

Course code: AME2 — ECTS Credits: 1

Department	: ET	**Lectures**	: 8h45
Lecturers	: A. Claverie	**Tutorials**	:
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 2nd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 8h45
Type of courses	: Compulsory		

Objective: This course main goal is to describe several measurement methods which are commonly used in fluid mechanics.

Prerequisites: Basic knowledge in fluid mechanics, heat transfer and combustion

Content:

Several methods for the visualization and measurement of fluid velocity, of pressure and of concentration. These methods are more precisely described below, divided into several parts:

- **Vizualisation:** chemiluminescence, schlieren, shadowgraphy, interferometry, laser tomography
- **Pressure and Flow rate measurement**
- **Concentration measurement:** chromatography, Planar Laser Induced Fluorescence, spectroscopy
- **Velocity measurement:** Laser Doppler Velocimetry (LDV) and Particle image velocimetry (PIV)

Recommended reading: None

BACK

Semester 2
Major: High Temperature Materials (HTM)

Vibrations – Finite Elements			
Course code: AVF2		**ECTS Credits: 5**	
Department	: MSISI	**Lectures**	: 15h00
Lecturers	: M. Beringhier	**Tutorials**	: 12h30
Year of study	: 1st year	**Laboratory sessions**	: 15h00
Semester	: 2nd semester	**Project**	:
Assessment method(s)	: 1 written test + practicals	**Home works**	:
Language of instruction	: English	**Total hours**	: 42h30
Type of courses	: Compulsory		

Objective: To learn how to analyse the results given by F.E.M. for trusses and beams structures.

Prerequisites: course of structure mechanics

Content:

1. **Finite element**
   - Structural framework
   - F.E.M. applied to a 2D problem solving
2. **Vibrations**
   - Vibrations of single degree of freedom systems
   - Vibrations of multiple degree of freedom ystems
   - Vibrations of rectilinear beams

Recommended reading:

J.F. Imbert, *Analyse des structures par éléments finis*, Cépaduès, 1991
J.N. Reddy, *An introduction to the finite element method*, Mac GrawHill, 1993
B. Drouin, J.M. Senicourt, F. Lavaste, G. Fezans, *De la mécanique vibratoire classique à la méthode des éléments finis,* Volumes 1 et 2, AFNOR, 1993
A.A. Shabana, *Theory of Vibration, an introduction*, Springer-Verlag, 1996
M. Del Pedro, Pierre Pahud, *Mécanique vibratoire*, Presses Polytechniques et Universitaires Romanes, 1989
M. Gérardin, D. Rixen, *Théorie des vibrations – Application à la dynamique des structures*, Masson, 1993
Zienkiewicz O.C., *The Finite Element Method*, 4th edition, 2 volumes, Mc Grow Hill, 1989
Batoz J.L., Dhatt G., *Modélisation des structures par éléments finis*, 3 volumes, Hermès, 1990

BACK

Structures/Materials Project

Course code: ASM2 — ECTS Credits: 4.5

Department	: MSISI	**Lectures**	:
Lecturers	: G. Hénaff, C.Nadot	**Tutorials**	:
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 2nd semester	**Project**	: 18h00
Assessment method(s)	: 1 project	**Home works**	:
Language of instruction	: English	**Total hours**	: 18h00
Type of courses	: Compulsory		

Objective: The aim of the course is to learn how to use industrial Finite Element software (Abaqus) and apply the acquired knowledge to structures calculation for the control of a structure.

Prerequisites: 2nd year courses of structures mechanics (MDS3) and finite elements (MEF4)

Content: Study of the footbridge of a structure with beams and plates

- The structure being provided, the students have to construct the model of the structure, by making it simpler. They also have to determine the stresses on such simplified structure.
- Use of the ABAQUS software of calculation by finite element: students, working in pairs, will build a model and will calculate the displacements, the load and the stresses of each element of the structure.
- Visual display of the results with the Femgy software. Critical study of the results, and behaviour control of the structure.
- Calculus of the frequencies and Eigen modes of vibrations by finite element.
- X ray diffraction analysis of copper alloys. Comparison between experiments and simulation of diagrams. Observation of cold work materials texture.

Recommended reading: None

BACK

Materials science

Course code: AMS2 — ECTS Credits: 5

Department	: MSISI	**Lectures**	: 13h45
Lecturers	: G. Henaff	**Tutorials**	: 12h30
Year of study	: 1st year	**Laboratory sessions.**	: 12h00
Semester	: 2nd semester	**Project**	:
Assessment method(s)	: 2 written tests, practicals	**Home works**	:
Language of instruction	: English	**Total hours**	: 38h15
Type of courses	: Compulsory		

Objective: To understand the relation between structure and mechanical properties. To be able to define a heat treatment. To be able to select a material in structural design.

Prerequisites: none

Content:

1. **Ferrous alloys**
   - Microstructures at equilibrium of stells and cast irons
   - Heat treatments (quenching and tempering, isothermal transformations)
   - Different classes of steels
2. **Non ferrous metals**
   - Aluminium alloys
   - Copper alloys
   - Titanium alloys
   - Nickel-based superalloys
3. **Mechanical properties**
   - Mechanical Testing (Hardness - Tensile test – Impact test- Creep test)
   - Stress-strain behaviour
   - Failure
   - Creep behaviour and damage
4. **Materials selection in mechanical engineering**

Recommended reading: None

BACK

Helicopters

Course code: AHE2 — ECTS Credits: 1.5

Department	: ET	**Lectures**	: 12h30
Lecturers	: D. Bertin	**Tutorials**	:
	(guest speakers/ *extérieurs*)	**Laboratory sessions**	:
Year of study	: 1st year	**Project**	:
Semester	: 2nd semester	**Home works**	:
Assessment method(s)	: 1 written test	**Total hours**	: 12h30
Language of instruction	: English		
Type of courses	: Compulsory		

Objective: Understanding of flight mechanics specific to helicopters, as well as how is working a rotor. Understanding the ground resonance phenomena related to a rotor/structure coupling

Prerequisites: None

Content:

Part 1: Rotor and flight mechanics – Rotors' technologies

1. Rotor mechanics and helicopter flight mechanics: buffeting, drag equation, rotor hinges, rotor control (piloting), longitudinal and lateral balance of the aircraft in stationary mode and in horizontal flight position.
2. Ground resonance: phenomena description, fluid/structures coupling, description of the role of the frequency adaptors.
3. Rotors' technologies: give an overview of the concepts, the technologies and materials used for the main and tail helicopter rotors, for Eurocopter and other companies

Part 2: General architecture, design, survivability

1. Vehicle's general architecture: description of the different architectures (civil, military aircrafts), the main components, tracking, the networks and segregation principles
2. The structure and the « equipment » (fuel, gear, internal lay out, missions' options, air conditioning systems) : the constructive principles of the structures, and the technologies, the structure's equipments, their role, the design
3. The survivability: the concept of crash protection, the design
4. The general design in preliminary projects : rotors' design, performances
5. Dynamic units of helicopters (transmission, rotor), their role and design : parameters for rotors design, causes of static and fatigue resistance

Part 3: Helicopter flight performances

1. Presentation of the principle
2. Required power : Froude Theory, required power for stationary flights, required power in forward flight, reduced characteristic quantities: reduced mass /reduced power, required power distribution
3. Expendable power : engine power/Engine speeds, power loss upon installation, gearbox restrictions
4. Restrictions (flight envelope, Never exceed speed, MGW, reduced mass…)
5. Analysis of the specificities of the helicopter performances thanks a determined model
6. Presentation of the aspects of the take-off performances related while taking into account the engine failure: notions on height-velocity diagram and Fly-away, presentation of the performance class (JAR-OPS 3), procedures of associated take-off, analyses of the parameters that determine these performances
7. Presentation of the « mission's calculation » aspects : modelling, emphasis of the iteration process to be applied, Payload/Range chart, examples

Recommended reading: None

BACK

Project

Course code: APR2 — ECTS Credits: 8

Department	: N/A	**Lectures**	:
Lecturers	: N/A	**Tutorials**	:
Year of study	: 1st year	**Laboratory sessions**	:
Semester	: 2nd semester	**Project**	: 270h00
Assessment method(s)	: 1 project	**Home works**	:
Language of instruction	: English	**Total hours**	: 270h00
Type of courses	: Compulsory		

Objective : This course allows an individual student to undertake a research project on a specific field of his or her choice related to aeronautical and mechanical engineering. The project must have a clearly defined topic, which has been approved by the academic supervisor of the project.

Prerequisites: None

Content:
The course aims to familiarise the student with and to develop skills in formulating research topics, conducting independent research, using individual supervision, and writing coherent, informative, and persuasive papers.

Recommended reading: None

BACK

Semester 3
Common-core syllabus

French as a foreign language (FLE)			
Course code: AFL3		**ECTS Credits: 1,5**	
Department	: FGH	**Lectures**	: 21h00
Lecturers	: C Maissin	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: written tests + continuous assessment	**Home works**	:
Language of instruction	French	**Total hours**	: 21h00
Type of courses	: Compulsory		

LEVEL 1 (A1 - BREAKTHROUGH)

Prerequisites: None

Objectives:
• Being able to understand a conversation, full sentences and basic information about everyday life.
• Being able to answer basic questions and describe one's everyday life environment with basic vocabulary.
• Being able to fill up a form, to write a short message or a letter in order to get basic information.

Content:
• Courses are based on the CEFRL (Common European Framework of Reference for Languages).
• Use of communicative approach to language acquisition based on a textbook, various semi-authentic oral and written documents...
• Special emphasis on oral comprehension and expression.

Communicative themes:
Module 1: Talking about yourself
Module 2: Exchange
Module 3: Working in Space
Module 4: Lying in time

Recommended reading:
- Watching French TV,
- Listening to French radio,
- Reading French newspapers,

Web sites: www.lepointdufle.fr; www.fle.fr…

French culture

Course code: AFC3 — ECTS Credits: 1,5

Department	: FGH	**Lectures**	: 21h00
Lecturers	: E Corioland	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions** .	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: written tests + continuous assessment	**Home works**	:
		Total hours	: 21h00
Language of instruction	: French		
Type of courses	: Compulsory		

Objective: Provide French culture understanding

Prerequisites: None

Content:
Completing the non-French speaking students' academic background in order to enable them to:

- Understand their counterparts in different situations
- Be able to communicate in everyday French language
- Get a better approach into French culture and help them carve out a place into French society during their studies

Listening comprehension, speaking, reading comprehension and writing through videos and recordings. Studying French culture and today's French Society.

Recommended reading: None

BACK

Turbulence

Course code: ATU3		ECTS Credits: 2.5	
Department	: MFA	**Lectures**	: 15h00
Lecturers	: J. Borée	**Tutorials**	: 15h00
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 30h00
Type of courses	: Compulsory		

Objective: To give the students a good physical and phenomenological understanding and to introduce the strength and limitations of standard and advanced turbulence models

Prerequisites: Advanced fluid mechanics

Content of courses

1. Introduction
2. Statistical description of the turbulent flows
3. Mean-flow equations
4. Mean and turbulent kinetic energy budgets
5. The scales of turbulent motion
6. Free shear flows
7. Wall flows
8. Modelling and simulation of turbulent flows

Content of the classes

1. Turbulent mixing: application to the internal combustion engine
2. Statistical convergence for the measurement of a turbulent flow
3. Energy cascade and Kolmogorov hypotheses
4. Budgets of the Reynolds stresses

5/6. Homogeneous turbulence. Its distortions in liaison with the development of models

7/8. Self-preserving turbulent plane wake

9/10. Wall flows. Physical analysis and modelling

11/12. Numerical computation of a plane channel flow. On the use of law of the wall closures

Recommended reading:

S.B. Pope, *Turbulent flows*, Cambridge University Press, 2000
P. Chassaing, *Turbulence en mécanique des fluides*, Editions Cepadues, 2000

BACK

Combustion

Course code: ACO3 — ECTS Credits: 2.5

Department	: ET	**Lectures**	:
Lecturers	: M. Bellenoue	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test + practicals	**Home works**	:
Language of instruction	: English	**Total hours**	: 38h45
Type of courses	: Compulsory		

Objective: Knowledge of the fundamentals of laminar combustion

Prerequisites: Thermodynamics, fluid mechanics

Content:

1. Introduction
2. Conservative equations for multicomponents reacting system
3. Phenomenological relations – Chemical kinetics
4. Diffusion flames
5. Premixed laminar flames
6. Turbojet engines' combustion in combustion chambers
7. Ignition and extinction

Recommended reading: None

BACK

Atomisation Two Phase flow

Course code: APF3 — ECTS Credits: 1.5

Department	: ET	**Lectures**	: 15h00
Lecturers	: FX Demoulin	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 15h00
Type of courses	: Compulsory		

Objective: To give the students an overview of atomization phenomena which are involved during injection of fuel. Nowadays methods dedicated to spray and atomization will be explained from both experimental and numerical points of view. Finally a representative selection of injectors that can be encountered in real engine will be characterized to explain their typical range of application.

Prerequisites: Good knowledge of fluid mechanics

Content:

1. **Physical mechanisms**
   - Comprehension of atomization phenomena through different experimental results
   - Characteristic mechanisms and their associated dimensionless numbers: Re, We, Fr, Oh
   - Notion about linear instability to build a simple scenario of atomization from the liquid jet to the final droplet
2. **Methods**
   - Basic principle of experimental methods dedicated to spray: shadowgraphy, Mie scattering, LDV, PIV, PDPA
   - (Optional) advance technics: X-ray, Phemto laser
   - Basic principle of numerical methods for atomisation: RANS-Lagrangian based method with primary breakup model, secondary break-up model, collision modelling
   - Direct numerical method with interface capturing approach: VOF, Level Set
   - (Optional) advance numerical technics: ELSA, LES, numerical representation of discontinuity
3. **Injector applications**
   - Single hole injecto
   - Swirl injector
   - Air blast atomizer

Recommended reading:

Arthur Henry Lefebvre, *Atomization and Sprays*, Taylor & Francis Inc (1 December 1988)
G. Tryggvason, R. Scardovelli and S. Zaleski, *Direct Numerical Simulations of Gas-Liquid Multiphase Flows,* Cambridge University Press, 2011

Two-phase combustion

Course code: APC3 — ECTS Credits: 1.5

Department	: ET	**Lectures**	: 15h00
Lecturers	: Z.Bouali	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 15h00
Type of courses	: Compulsory		

Objective: providing the student with physical and phenomenological bases that will enable them to deal with practical applications related to propulsive systems

Prerequisites: Basics of combustion and fluid mechanics

Content:

- Basic of two-phase flows thermodynamics
- Phenomenological dscription of vaporization processes
- Heat and mass transfer in two-phase flows (isolated droplet)
- Determination of the vaporization rate (liquid droplet and liquid sheet)
- Locally homogeneous flows and separated flows models
- Combustion of sprays and spray combustion diagrams (Chiu, Borghi)
- Preferential segregation effects
- Mixture fraction formalism, derivation of the transport equations for the average and variance of the mixture fraction field
- Two-phase flows turbulent combustion modelling (SDM, MIL)

Recommended reading:

R. Borghi and M. Destriau, *La combustion et les flammes*, Technip, 1997
R. Borghi and M. Champion, *Modélisation et théorie des flammes,* Technip, 2000
K.K. Kuo, *Principles of combustion*, Wiley, 1986
K.K. Kuo, R. Acharya, *Fundamentals of turbulent and multiphase combustion*, Wiley, 2012
M. Lackner, F. Winter, A.K. Agarwal, *Handbook of combustion*, Vol. 1, Wiley, 2010
C.K. Law, *Combustion physics*, Cambridge University Press, 2010
F.A. Williams, *Combustion theory*, Benjamin Cummins (Menlo Park), 1985

BACK

Turbulent combustion

Course code: ATC3 — ECTS Credits: 1.5

Department	: ET	**Lectures**	: 15h00
Lecturers	: A. Mura	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 15h00
Type of courses	: Compulsory		

Objective: providing the student with physical and phenomenological bases of turbulent combustion

Prerequisites: Basics of combustion and fluid mechanics

Content:

1. **Basics of laminar flames structures:** Multicomponent reactive Navier-Stokes equations at low Mach number, simplification at unity Lewis number, coupling terms, stirred reactor concept (« thickened flames »): finite rate chemistry effects, introduction of the Damköhler number, premixed flame structures: characteristic thickness and propagation velocity, influence of strain and curvature, introduction of the progress variable, non premixed flames : introduction of the mixture fraction variable, application to the counterflow diffusion flame, phase diagrams and permitted domain, influence of in-plane strain-rate
2. **Basics of turbulence and closure problem associated with the reactive scalar**

Turbulence: characteristic time scales and length scales, spectral dynamics, direct numerical simulation versus LES or RANS modelling frameworks, classsical closures: RANS k-eps and LES Smagorinsky, mean (or filtered) reaction rate: closure attempts, fast and slow chemistry limits, turbulent transport closures

3. **Premixed turbulent flames and combustion**

Effects of the fluctuating velocity field, phenomenology as revealed from Bradley's experiments, the turbulent burning velocity and its possible relevance, combustion regimes and diagrams (Borghi, Peters), the thin flame limit, modelling strategies: principles of modelling, similarities and differences between the standard approaches, limits of available closures and current trends for further developments

4. **Non premixed turbulent flames and combustion**

Combustion regimes and flame structures, interaction with turbulence, high Da flames (chemical equilibrium), finite-rate chemistry effects and local extinctions, associated closures: algebraic models and transport équations, PDF closures, principles, panorama et limitation of available closures, non premixed flame stabilization and triple flame structures, partially premixed combustion

Recommended reading:

M. Barrère, R. Prudhomme, *Equations fondamentales de l'aérothermochimie*, Masson Eds., 1973
J.D. Buckmaster, G.S.S. Ludford, *Theory of laminar flames*, Cambridge University Press, 1982
Ya.B. Zeldovich, G.I. Barenblatt, V.B. Librovich, G.M. Makhviladze, *The mathematical theory of combustion and explosions*, Consultant Bureau, Plenum Publishing Corp., 1985
N. Peters, *Turbulent combustion*, Cambridge University Press, 2000
S.B. Pope (2000), *Turbulent flows*, Cambridge University Press
A. Favre (1976), *La turbulence en mécanique des fluides*, A. Favre, L.S.G. Kovasznay, R. Dumas, J. Gaviglio, M. Coantic (Eds.), CNRS Editions, 1976
H. Tennekees, J. Lumley (1972), *A first course in turbulence*, The MIT Press, Cambridge (Massachussets), 1972
V.R. Kuznetsov, V. Sabelnikov, *Turbulence and combustion*, Hemisphere Publishing Corporation, 1990
R. Fox, *Computational models for turbulent reacting flows*, Cambridge University Press, 2002.
R. Borghi and M. Destriau, *La combustion et les flammes*, Technip, 1997
R. Borghi and M. Champion, *Modélisation et théorie des flammes,* Technip, 2000
R.S. Cant and E. Mastorakos, *An introduction to turbulent reacting flows*, Imperial College Press, 2008
K.K. Kuo, *Principles of combustion*, Wiley, 1986
K.K. Kuo, R. Acharya, *Fundamentals of turbulent and multiphase combustion*, Wiley, 2012
M. Lackner, F. Winter, A.K. Agarwal, *Handbook of combustion*, Vol. 1, Wiley, 2010
C.K. Law, *Combustion physics*, Cambridge University Press, 2010
F.A. Williams, *Combustion theory*, Benjamin Cummins (Menlo Park), 1985

BACK

Turbomachinery

Course code: ATM3 — ECTS Credits: 2

Department	: MFA	**Lectures**	: 12h30
Lecturers	: A. Spohn	**Tutorials**	: 12h30
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours** *Horaire*	: 25h00
Type of courses	: Compulsory		

Objective: To provide the student with working knowledge of the fluid mechanics of turbomachinery elements (flow inlets, compressors and turbines)

Prerequisites: Compressible fluid mechanics, notions of turbulent flows, thermal engines

Content:

1. Introduction, overview and machinery classification
2. Two-dimensional flow in a compressor and a turbine stage
3. Two-dimensional cascades and airfoils
4. Simplified three-dimensional flow
5. General design criteria for compressors and turbines
6. Radial compressor
7. Stable operation and off design operation

Recommended reading:

S.L. Dixon, *Fluid Mechanics, Thermodynamics of Turbomachinery*, Pergamon Press Second Edition, 1975
B. Lakshminarayana, *Fluid Dynamics and Heat Transfer of Turbomachinery*, John Wiley and Sons Inc., 1996

BACK

Rocket propulsion

Course code: ARP3 — ECTS Credits: 1.5

Department	: ET	**Lectures**	: 15h00
Lecturers	: C.Bonhomme	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 15h00
Type of courses	: Compulsory		

Objective:

Prerequisites:

Content:

1. **Introduction to solid propellant rocket motors** (history, classification, application)
2. **Performances of solid propellants**: mixture ratio, colloidal (homogeneous) propellants, heterogeneous (composite) propellants, double-based propellants, theoretical performances calculations, experimental determination of performance
3. **Motor operation**: ignition, burning rate laws, grain cross-section versus thrust profiles,
4. **Steady-state solid propellant combustion**: aerothermochemistry bases, combustion of homogeneous solid propellants (adiabatic and non adiabatic), combustion of components of composite propellants, combustion of heterogeneous solid propellant, and combustion of metal particles
5. **Ignition and extinction** of solid propellants, **erosive burning**, combustion **instability**

Recommended reading:

BACK

Radiation in semi-transparent environment

Course code: ART3 — ECTS Credits: 2

Department	: ET	**Lectures**	: 12h30
Lecturers	: D. Lemonnier	**Tutorials**	: 12h30
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 25h00
Type of courses	: Compulsory		

Objective: Understanding of radiative heat transfer in semi-transparent media (physics, energy balance, equations, principle of temperature field calculation).

Prerequisites: Basic laws for radiative heat transfer (Planck, Wien, Stefan, thermo optical properties of surfaces, view factors, balance equations).

Content:

- Radiative heat transfer with multireflections,
- Introduction to physics and modelling of semi transparent media (absorption, emission, energy balance, examples of materials and industrial domains of interest),
- Intensity equation and energy equation; optically thin and optically thick media (Rosseland approximation),
- Hottel diagrams,
- Heat flux exchanged in the case of a gray semi transparent medium (mean hemispherical beam, couplings evaluation, multi reflections),
- Basic laws of atomic and molecular physics for gas radiation analysis,
- Lines shapes (broadening, intensity),
- Models of emission spectrum,
- Principle of temperature field calculation.

Recommended reading: Hottel et Sarofim (1967), Siegel et Howell (1981); Modest (1983); Brewster (1992)

BACK

Turbulent heat exchange

Course code: ATH3 — ECTS Credits: 1

Department	: ET	**Lectures**	: 20h00
Lecturers	: L. Brizzy	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 20h00
Type of courses	: Compulsory		

Objective: The purpose of this course is to provide a description of the mechanisms involved in the heat transfer in the presence of turbulent flows. It should enable the student to know the role of turbulence on heat transfer for the main industrial configurations. The last part of the course is an extension of the course on turbulence modelling applied to heat transfer.

Prerequisites: None

Content:

1. Reminder of the characteristics of the dynamic and thermal turbulence.
2. Heat transfer in turbulent parietal flows (flow in pipes - boundary layer)
3. Turbulent free flows in natural, mixed and forced convection.
4. RANS Turbulence modeling : Thermal aspects.

In the lecture is associated tutorials, in pairs, to calculate heat transfer in industrial configurations.

Recommended reading: None

BACK

New combustion mode for propulsion

Course code: ACP3		ECTS Credits: 2	
Department	: ET	**Lectures**	: 7h30
Lecturers	: R. Zitoun	**Tutorials**	: 6h15
Year of study	: 2nd year	**Laboratory sessions**	: 3h00
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: written tests	**Home works**	:
Language of instruction	: English	**Total hours**	: 16h45
Type of courses	: Compulsory		

Objective: To give basic concepts on shock and detonation physics to allow the understanding of the the detonation propulsion systems. We first focus on physical models and structure of detonation wave and then presents the main concepts of propulsion by detonation currently studied.

Prerequisites: Thermodynamics, fluid mechanics

Content:

1. Detonation phenomenology
2. Detonation models
3. Flow of detonation products
4. Detonation dynamics and structure
5. Detonation and propulsion:

Continuous Detonation Wave Engine (CDWE)

- Principle
- History
- Modelisation
- Examples and Perspectives

Pulse Detonation Engine (PDE)

- Principle
- History
- Examples and Perspectives

Others non-conventional aeronautical engines: CVC, Combine Cycle Engine etc…
Programs: US VAATE, ADVENT, FALCON etc…

Recommended reading:

"Detonation: Theory and Experiment", Wildon FICKETT and William C. DAVIS, Dover Publications, 2000, ISBN-13: 978-0-486-41456-0,
"The detonation phenomenon" John H.S. Lee, CAMBRIDGE University Press, 2008, ISBN 978-0-521-89723-5

BACK

Numerical combustion for engines

Course code: ANC3 — ECTS Credits: 2

Department	: ET	**Lectures**	: 5h00
Lecturers	: V. Robin	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	: 27h00
Assessment method(s)	: 1 written test, 1 project	**Home works**	:
Language of instruction	: English	**Total hours**	: 32h00
Type of courses	: Compulsory		

Objective: To be able to perform a numerical simulation of academic or industrial reactive flows.

Prerequisites: Combustion, Turbulence, Turbulent Combustion, and Basic of Numerical Methods

Content:

1. **Prior to computation.**
   - Geometry and Meshes
   - Boundary and Initial Conditions
   - Fluid properties
2. **Getting started with a Computational Fluid Dynamic solver.**
   - Range of possibilities
   - Basic settings and adjustments
   - Simulation tests
3. **Numerical simulations**
   - Non reactive
   - Reactive
   - Laminar and turbulent reactive flows
4. **Results analysis**
   - Sensitivty of numerical parameters
   - Models behaviors
   - Presentation

Recommended reading:

R. Borghi, M. Champion, *Modélisation et théorie des flames*, Editions TECHNIP, 2000
T. Poinsot, D. Veynante, *Theoretical and Numerical Combustion*, Edwards, 2005
N. Swaminathan, K.N.C. Bray, *Turbulent Premixed Flames*, Cambridge University Press, 2011

Semester 3
Major High Temperature Materials (HTM)

Finite Elements modelling			
Course code: AFE3		**ECTS Credits: 2.5**	
Department	: MSISI	**Lectures**	: 15h00
Lecturers	: J.Genée, V.Robin	**Tutorials**	: 15h00
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 30h00
Type of courses	: Compulsory		

Objective: Understand the finite element method and the numerous techniques used in an industrial software

Prerequisites: course of finite element

Content:

1. Fundamentals
2. Mechanic Formulations (Balance equation)
3. Isoparametric elements, interpolation functions
4. Numerical integration of stiffness matrix
5. Condensation and superelements
6. Element selection and meshing errors
7. Assembly procedures and solution of linear algebraic equations

Recommended reading: J-F. Imbert, *Analyse des structures par éléments finis*, Cepadues

BACK

Plasticity-Viscoplasticity

Course code: APV3		ECTS Credits: 2.5	
Department	: MSISI	**Lectures**	: 15h00
Lecturers	: D. Halm	**Tutorials**	: 15h00
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 30h00
Type of courses	: Compulsory		

Objective: Learning classical tools to simulate rate-independent plasticity and viscoplasticity

Prerequisites: Solid mechanics

Content:

1. Introduction to nonlinear mechanics
2. Elasto-visco-plastic behaviour
3. Isotropic hardening – Prandtl-Reuss model
4. Kinematic hardening
5. Other plasticity criteria
6. Viscoplasticity

Recommended reading:

J. Lemaitre, J-L. Chaboche, *Mécanique des matériaux solides*, Dunod, 1988
D. François, A. Pineau, A. Zaoui, *Comportement mécanique des matériaux*, Hermes, 1995
J. Besson, G. Cailletaud, J-L. Chaboche, S. Forest, *Mécanique non linéaire des matériaux*, Hermes, 2001

BACK

Materials mechanical properties

Course code: AMM3 — ECTS Credits: 2.5

Department	: MSISI	**Lectures**	: 15h00
Lecturers	: J.Cormier	**Tutorials**	: 15h00
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 30h00
Type of courses	: Compulsory		

Objective: Connect the macroscopic and microscopic aspects of metals and metal alloys mechanical properties.

Prerequisites: Materials science

Content:

1. **Materials elasticity behavior**
   - Isotropic and anisotropic materials
   - Ealsticity constants
   - Measurement techniques
2. **Anelastic behavior**
   - Anelasticity (creep, absorption, relaxation, damping)
   - Linear and non linear models (Rheology)
   - Physical origin of anelasticity, Applications
3. **Plastic behavior**
   - Plastic deformation of solids
   - Stress-deformation relations on micro and macroscopic scales
   - Cristalline defects

Recommended reading:

Physique des Matériaux, Quéré, Eds. Ellipses.
Dislocations et Plasticité des Cristaux, Martin, Presses Polytechniques et Universitaires Romandes

Fracture mechanics

Course code: AFM3 — ECTS Credits: 1

Department	: MSISI	**Lectures**	: 6h15
Lecturers	: C. Gardin	**Tutorials**	: 6h15
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 12h30
Type of courses	: Compulsory		

Objective: Take into account a stress concentrator or a crack during dimensioning of a structure under static or cyclic loading

Prerequisites: Solid mechanics

Content:
Fracture mechanics

- Different types of fracture
- Linear fracture mechanics
- Elastoplastic fracture mechanics

Recommended reading: D. François, A. Pineau, A. Zaoui, *Comportement mécanique des matériaux*, Hermes, 1995

BACK

Fatigue

Course code: AFA3 — ECTS Credits: 1

Department	: MSISI	**Lectures**	: 07h30
Lecturers	: G. Hénaff	**Tutorials**	: 07h30
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 15h00
Type of courses	: Compulsory		

Objective: Take into account a stress concentrator or a crack during dimensioning of a structure under static or cyclic loading

Prerequisites: Solid mechanics

Content:

1. Fatigue damage (crack initiation, crack propagation)
2. Cyclic stress strain behaviour – Low cycle fatigue
3. High cycle fatigue
4. Fatigue of notched components
5. Fatigue crack growth

Recommended reading: D. François, A. Pineau, A. Zaoui, *Comportement mécanique des matériaux*, Hermes, 1995

BACK

Atomic diffusion and applications

Course code: AAD3 — ECTS Credits: 2

Department	: MSISI	**Lectures**	: 10h00
Lecturers	: V. Pelosin	**Tutorials**	: 8h45
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 18h45
Type of courses	: Compulsory		

Objective: Knowledge on atomic diffusion mechanisms involved in many industrial processes.

Prerequisites: Materials science

Content:

1. **Atomic diffusion**
   - Macroscopic diffusion, Fick's laws
     - Elementary diffusion mecanisms, crystalline diffusion
     - Diffusion applications
2. **Phase transformations**
   - Thermodynamic approach
   - Free energy of solid solutions
   - Germination and growth mechanisms
   - Determination of the transformation kinetics
   - Diffusive and displacive phase transformation

Recommended reading: None

High Temperature Alloys

Course code: AHT3 — ECTS Credits: 2

Department	: MSISI	**Lectures**	: 15h00
Lecturers	: G. Hénaff	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 15h00
Type of courses	: Compulsory		

Objective: Overview of alloys used in high-temperature applications: Titanium-, Nickel- and Cobalt-based alloys, Intermetallics, Silicides

Prerequisites: Materials Science & Engineering

Content:
Metallurgy and microstructure optimization for improved mechanical properties (tensile, creep, fatigue, dwell-fatigue, crack propagation) of the following classes of alloys:

- Titanium-based alloys
- Nickel-based superalloys (Polycristalline, Directionnaly Solidified and Single Cristalline alloys)
- Cobalt-based alloys
- Intermetallics (TiAl, FeAl alloys, …), Silicides, Niobium based alloys

Recommended reading:
The Superalloys – Fundamental and Applications, R.C. Reed, Cambridge University Press, 2006

BACK

Thermal Barrier Coatings for Gas Turbine Engine

Course code: ATB3 — ECTS Credits: 1

Department	: MSISI	**Lectures**	: 12h00
Lecturers	: G. Hénaff, M. Vardelle (guest speaker)	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 12h00
Type of courses	: Compulsory		

Objective: Overview of thermal barrier coating technology and degradation processes

Prerequisites: Materials Science & Engineering

Content: Thermal barrier coatings (TBC) operate in high-temperature environment of aircraft engines and are used to provide thermal insulation and to protect structural engineering materials from corrosion and erosion. They are now widely used in modern gas turbine engines to lower the metal surface temperature in combustor and turbine section hardware and so to improve the durability and energy efficiency of engines.

They are generally a complex combination of multiple layers of coatings, with each layer having a specific function and requirement. In this lecture, the current processes used to manufacture TBC, their structure, properties, and failure mechanisms will be reviewed. Also, the current limitations and present development will be discussed.

Recommended reading:

History of Thermal Barrier Coatings for Gas Turbine Engine, Robert A. Miller, NASA/TM—2009-215459
Thermal-Barrier Coatings for Advanced Gas-Turbine Engines, Dongming Zhu and Robert A. Miller, MRS Bulletin, Volume 25, Issue 07, July 2000, pp 43-47
Thermal Barrier Coating Materials, David R. Clarke and Simon R. Phillpot, Materials today, Volume 8, Issue 6, June 2005, Pages 22–29
Thermal Barrier Coatings for the 21st Century, M. J. Stiger, N. M. Yanar, M. G. Topping, F. S. Pettit, and G. H. Meier
Thermal Barrier Coatings for Gas-Turbine Engine Applications, Nitin P. Padture, Science 12 April 2002: Vol. 296 no. 5566 pp. 280-284
Emerging materials and processes for thermal barrier systems, Carlos G. Levi, Current Opinion in Solid State and Materials Science 8 (2004) 77–9

BACK

Materials processing

Course code: AMP3 — ECTS Credits: 2

Department	: MSISI	**Lectures**	: 24h00
Lecturers	: G. Hénaff, C. Dumont (Aubert&Duval) (guest speaker)	**Tutorials**	:
		Laboratory sessions	:
Year of study	: 2nd year	**Project**	:
Semester	: 3rd semester	**Home works**	:
Assessment method(s)	: 1 written test	**Total hours**	: 24h00
Language of instruction	: English		
Type of courses	: Compulsory		

Objective: Overview of the main deformation processing routes and of the different issues that have to be addressed to manufacture industrial components

Prerequisites: Materials Science & Engineering

Content:

- Microstructural transformations
- Process modelling
- Main processes (Drawing, Rolling, Forging, Punching…)

Recommended reading:

BACK

Engineering Failure Analysis

Course code: AEF3 — ECTS Credits: 1.5

Department	: MSISI	**Lectures**	: 6h00
Lecturers	: G. Hénaff, G. Saint-Martin (Turboméca) (guest speaker)	**Tutorials**	:
		Laboratory sessions	:
Year of study	: 2nd year	**Project**	:
Semester	: 3rd semester	**Home works**	:
Assessment method(s)	: 1 written test	**Total hours**	: 6h00
Language of instruction	: English		
Type of courses	: Compulsory		

Objective: Overview of failure analysis, mechanical and metallurgical investigations, and fractography (context, methodology, tools, capabilities, knowledge, goals, etc.).

Prerequisites: Materials Science & Engineering, Mechanical Engineering, Fracture Mechanics

Content:

1. **Framework of Failure Analysis**
   - Application Fields
   - Technical Assistance
   - Judicial Cases
   - Other Frameworks
2. **Methodology of Failure Analysis**
   - General Methods
   - Actors and Organisation
   - Preliminary Investigation
   - Laboratory Study
   - Check and Confrontation
   - Write and Act
3. **Mechanical and Metallurgical Investigation**
   - Methodological Aspects
   - Required Knowledge
   - Tools, Means and Ways
4. **Fractography**
   - Methodological Aspects
   - Material Science Bases
   - Fracture Families (Static, Fatigue, Creep, Corrosion, etc.)
   - How and Why
5. **Cases Studies**
   - Varied Aeronautical Cases

Recommended reading: None

BACK

Corrosion of engineering materials

Course code: ACE3 — ECTS Credits: 1

Department	: MSISI	**Lectures**	: 12h30
Lecturers	: L. Chocinski	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 12h30
Type of courses	: Compulsory		

Objective: The aim of this course is to underscore the importance of corrosion in industrial conditions and the links between other fields studied at ENSMA.

Prerequisites: Elementary knowledge in materials science

Content:

1. **Introduction and elementary knowledge**
   - Definition
   - Industrial importance and economy issue
   - Elementary knowledge (redox couples…)
2. **Dry corrosion: high temperature oxidation**
   - Mechanisms and examples
3. **Wet corrosion**
   - Mechanisms and electrochemical aspects
   - Modes of corrosion
   - Uniform corrosion, galvanic corrosion, pitting corrosion, crevice corrosion
   - Corrosion-deformation interactions (stress corrosion cracking, corrosion fatigue, hydrogen embrittlement)
4. **Corrosion in industrial field**
   - Aeronautics (cells: aluminium alloys, engines (Ti, Ni), coatings)
   - Power industry (steels, nuclear materials)
   - Mechanical engineering

Recommended reading: None

BACK

Creep

Course code: ACR3 — ECTS Credits: 1

Department	: MSISI	**Lectures**	: 12h30
Lecturers	: J. Cormier	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	:
Assessment method(s)	: 1 written test	**Home works**	:
Language of instruction	: English	**Total hours**	: 12h30
Type of courses	: Compulsory		

Objective: Presentation of engineering tools for the design under creep mechanical loading

Prerequisites: None

Content:
This course mainly intends to:

- Introduce the different creep strain mechanisms from a microstructural perspective
- Introduce phenomenological and physical models allowing to describe creep in terms of behavior and life-time (by taking into account the behavior-damage coupling)
- Introduce the consideration of thermal transients and the interactions with other types of loadings (fatigue, oxidation, corrosion)
- Implement the engineering tools allowing taking into account creep in the design of structures (life-time estimation with Larson-Miller type or damage approaches; Chaboche and Dyson/M^c Lean type behavior laws)

The given examples in this course will mainly be the metallic materials used in aeronautical turbines.

Recommended reading: None

BACK

Project

Course code: APR3		ECTS Credits: 7	
Department	: DE	**Lectures**	:
Lecturers	: N/A	**Tutorials**	:
Year of study	: 2nd year	**Laboratory sessions**	:
Semester	: 3rd semester	**Project**	: 120h00
Assessment method(s)	: 1 project	**Home works**	:
Language of instruction	: English	**Total hours**	: 120h00
Type of courses	: Compulsory		

Objective: This course allows an individual student to undertake a research project on a specific field of his or her choice related to aeronautical and mechanical engineering. The project must have a clearly defined topic, which has been approved by the academic supervisor of the project.

Prerequisites: None

Content:
The course aims to familiarise the student with and to develop skills in formulating research topics, conducting independent research, using individual supervision, and writing coherent, informative, and persuasive papers.

Recommended reading: None

Semester 4
Master thesis

Master thesis			
Course code: FPR4		**ECTS Credits: 30**	
Department	: DE	**Lectures** *Cours*	:
Lecturers	: N/A	**Tutorials** *T.D*	:
Year of study	: 2nd year	**Laboratory sessions** *T.P.*	:
Semester	: 4th semester	**Project** *Projet*	: 6 months
Assessment method(s)	: 1 project	**Home works** *Non encadré*	:
Language of instruction	: English	**Total hours** *Horaire global*	: 6 months
Type of courses	: Compulsory *Obligatoire*		

Objective: Students see the project through, from the design stage to test analysis

Prerequisites: None

Content:

Placed at the end of the academic training, this last internship can be carried out within a company or a research institution, in France or abrod. Students are given charge of a study, which a junior engineer should be able to conduct. This last internship is a real springboard for the integraton of young graduates onto the labour market.
Should an ENSMA co-supervisor agree to it, the graduation project can also count as a Research Master Project. Such internships (graduation cum Research Master Project) can be the opportunity for companies to make the most of ENSMA˝s research skills.
Duration of the internship: 3 to 6 months, from April to September

Recommended reading: None

BACK