CENTRALE NANTES

ENGINEERING PROGRAMME

2024-2025

Year 2 / Year 3

Specialisation option

Aeronautics

OD AERONAUTIQUE

PROGRAMME SUPERVISOR
Guy CAPDEVILLE

ENGINEERING - OD AERONAUTIQUE

Autumn Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 73	12	Core course	DYGAZA DYVOL ISN STAV	Gas dynamics Flight dynamics Introduction to numerical computation Aircraft structure modelling
UE 74	13	Core course	AEFP DYSTR MTURB P1AERO PROAE	Inviscid Aerodynamics Structural dynamics Turbulence Modeling Project 1 Aicraft propulsion

Spring Semester

Course unit	ECTS Credits	Track	Course code	Title
UE 83	14	Core course	AEAC CAE P2AERO SAE SPSAE	Aeroacoustics Aircraft design and construction Project 2 Computational aerodynamics Passive safety of aeronautic structures

Gas dynamics [DYGAZA]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Requirements

Objectives

A general introduction to the physics of compressible fluid flows with a bias towards aerodynamics.

Course contents

1. Fundamentals in aerodynamics
2. Equations for steady compressible fluid flow.
3. One-dimensional compressible fluid flow.
4. Waves in steady supersonic flows.
5. Jet Propulsion.
6. Practical exercices using STARCCM+.

Course material

[1] A.H. Shapiro, The dynamics and thermodynamics of compressible fluid flow, Vol. I, Ed. Ronald Press, (1953)
[2] M. J. Zucrow, J. D. Hoffman, Gas Dynamics, Vol. I, Ed. Wiley & Sons, (1976)
[3] J. D. Anderson, Modern compressible flows. With historical perspective, Ed. Mc GrawHill, (2003).

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	26 hrs	6 hrs	0 hrs	0 hrs	0 hrs

Flight dynamics [DYVOL]

LEAD PROFESSOR(S): Laurent PERRET

Requirements

Objectives

Based on the introductory course on aerodynamics, this course aims to describe and explain the flight characteristics and performance of planes through analysis of the lift and drag characteristics of airfoils, wings and the complete plane.

Course contents

1. Introduction
2. Fluid dynamics and aerodynamics
3. Lift
4. Drag
5. Mach number effect
6. Flight mechanics
7. Flight performance

Course material

- Aerodynamics, Aeronautics and Flight Mechanics, B.W. McCormick, Wiley;
- Introduction to Flight, J.D. Anderson, McGraw Hill;
- Flight Physics, E. Torenbeek & H. Wittenberg, Springer;
- Boundary Layer Theory, H. Schlichting & K. Gersten, Springer;
- Polycopié de Mécanique des Fluides, Pr J.-F. Sini, ECN

Assessment

Collective assessment: EVC 1 (coefficient 0.33)

Individual assessment: EVI 1 (coefficient 0.67)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	22 hrs	8 hrs	0 hrs	0 hrs	2 hrs

ENGINEERING - OD AERONAUTIQUE

Year 2 / Year 3 - Autumn Semester - Course Unit 73 / 93

Introduction to numerical computation [ISN]

LEAD PROFESSOR(S): Laurent GORNET

Requirements

Objectives

To provide an introduction to numerical modelling techniques.

Course contents

PDE classification. Elliptic/ Parabolic/Hyperbolic equations
Main discretisation techniques: finite difference, finite volume, finite element
Aerodynamic and structure examples
Fluid and structure examples with the code CasT3M (CEA)
PINNs, Deep Learning with TensorFlow (Partial differential equation)

Course material

Résolution numérique des équations aux dérivés partielles, A. Le. Pourhiet, Cepadues
Introduction à la méthode des éléments finis en mécanique des fluides, S. Gounand, CEA
A first course in Finite Elements, J. Fish, T. Belytschko, Wiley
Cours éléments finis, Centrale Nantes, H Oudin

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	8 hrs	8 hrs	0 hrs	0 hrs

Aircraft structure modelling [STAV]

LEAD PROFESSOR(S): Laurent GORNET

Requirements

Objectives

- Description of linear and nonlinear behavior laws for metallic and composite materials.
- Homogenization methods are presented for material and structure (composite beams).
- Simulations of crack initiation and propagation for static and fatigue loadings
- Finite Element prediction with Abaqus of aeronautic structures with beam, shell and continuum

Course contents

- Composite material homogenization techniques
- Fracture mechanics: energetic theory, singularity, crack propagations, example of fracture mechanics with a Finite Element code.
- Plasticity and instabilities
- Plasticity and instabilities for beam and shell models.
- Damage mechanics: method of local state, fatigue, phenomenology, behavior laws (metal and composite materials).
- Regularization techniques for stress softening behavior laws.
- Finite Element prediction until ultimate failure of aeronautic structures.
- Interactions between experimental data and behavior laws for material and structures

Course material

Aircraft Structures, for Engineering students, THG Megson, Butterworth Heinemann
Généralités sur les matériaux composites, L. Gornet, hal.archives-ouvertes.fr
Mécanique des matériaux solides, J. Lemaitre - JL Chaboche
Mechanics of Aircraft structures, C.T. Sun, Wiley

Assessment

Individual assessment: EVI 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	24 hrs	6 hrs	0 hrs	0 hrs	2 hrs

Inviscid Aerodynamics [AEFP]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Requirements

Objectives

- Introduce the conventional models for incompressible subsonic flow.
- Describe the modelling techniques derived from these models.
- Describe the evolution of ideas in aeronautics since the beginning of the nineteenth century
- The tutorials focus on programming one of the models introduced in the course.

Course contents

- Introductory principles in aerodynamics
- Fundamentals of inviscid incompressible flow - Kutta-Joukowski Theorem.
- Incompressible flow around airfoils - Numerical method of vortex singularities.
- Incompressible flow around wings - Prandtl's Lifting line theory.
- Linear theory of thin airfoils - Prandtl-Glauert's correction.
- Computation of aerodynamic features of an airfoil by using the method of singularities.

Course material

- J.D. Anderson, Fundamentals of aerodynamics, Ed. Mc Graw-Hill, (1984)
- A. H. Shapiro, The dynamics and thermodynamics of compressible fluid flow, Vol. I, Ed. Ronald Press, (1953).

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	24 hrs	8 hrs	0 hrs	0 hrs	0 hrs

Structural dynamics [DYSTR]

LEAD PROFESSOR(S): Pascal COSSON / Patrick ROZYCKI

Requirements

Elementary functions, Differentiation, Integration, Differential equations, Vector Analysis, Linear Algebra

Objectives

Aircraft commissioning - in order to ensure the safety of the passengers - requires controlling, for example, the frequencies and eigenmodes of the aircraft or of structural parts, but also controlling, for instance, the design of some structural parts such as landing gear. The course will provide the necessary knowledge for the implementation of such problems on the topics of motion and vibrations of multi-body systems. The numerical resolution of the above equations is also addressed in order to be able to propose solutions quickly when commercial software is not available.

The course has two main objectives. The first is related to the keys that are necessary to create elementary analytical models but sufficiently representative of the considered system in order to provide a quick overview of the solution. The second is to develop strong knowledge of numerical methods to solve the equations and to thus develop a critical eye as to the advantages/disadvantages of these methods.

From the knowledge obtained through this course, the students will propose a simple modelling and numerical resolution of a given problem. They will be able to analyse and critique these models and to confirm or refute the results obtained even when using commercially available software.

Course contents

1. Modelling a rigid bodies system
   - Configuration, joints, Lagrange's equations, kinematically or not admissible configuration etc.

2. Vibrations
   - Systems of 1 or more degree(s) of freedom, eigenvalue problem, free or forced vibrations etc.

3. Time integration schemes
   - Euler, Runge Kutta, Newmark, implicit or explicit methods, stability etc.

Course material

M. Géradin & A. Cardon, Flexible Multibody Dynamics - A Finite Element Approach, Wiley, 2001

D. Le Houedec, Mécanique des Solides, Nantes

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	12 hrs	8 hrs	12 hrs	0 hrs	0 hrs

Turbulence Modeling [MTURB]

LEAD PROFESSOR(S): Laurent PERRET

Requirements

Objectives

This course provides an introduction to turbulent flows and their numerical modelling.
It is completed by applications on the statistical analysis of a wake flow and the study of turbulence models using CFD code.

Course contents

1. Introduction
2. Turbulence phenomenology
3. The turbulent boundary layer
4. Statistical modeling of turbulence
5. Large Eddy Simulation

Course material

- Boundary Layer Theory, H. Schlichting & K. Gersten, Springer;
- Turbulent Flows, S.B. Pope, Cambridge univ Press;
- Turbulence en mécanique des fluides, P. Chassaing, Cépaduès

Assessment

Collective assessment: EVC 1 (coefficient 0.5)

Individual assessment: EVI 1 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	16 hrs	8 hrs	6 hrs	0 hrs	2 hrs

Project 1 [P1AERO]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Requirements

Objectives

Study and carry out a technical project in aeronautics in order to consolidate knowledge acquired in the specialisation.

Course contents

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	1	0 hrs	0 hrs	0 hrs	32 hrs	0 hrs

Aicraft propulsion [PROAE]

LEAD PROFESSOR(S): Vincent BERTHOMÉ

Requirements

Objectives

The objective of this course is to study in detail the thermodynamics of turbojet engines used in aeronautical propulsion.

Course contents

The course begins with the historical background of aeronautical propulsion and the associated stakes.

Following this, a presentation of aeronautical propulsion systems (turboshaft and turbojet engines) will be provided. The cycle of a single-flow turbojet engine will be studied as well as its operation without adaptation. Finally, a study of the turbofan engine will be presented.

The final part of the course deals with helicopter engines (general and thermal thermodynamics, role and operating principle, rotary wings).

Course material

Assessment

Individual assessment: EVI 1 (coefficient 0.5)
EVI 2 (coefficient 0.5)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	30 hrs	0 hrs	0 hrs	0 hrs	2 hrs

Aeroacoustics [AEAC]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Requirements

Objectives

Understanding and modelling the noise sources generated in a compressible turbulent flow.

Course contents

- Turbulence equations.
- Aeroacoustic analogies
- Specific numerical methods
- Examples: supersonic jets, cavities,...
- Computations using an aeroacoustic analogy

Course material

A. P. Dowling, J.E. Ffowcs-Williams, Sound and sources of sound, Ed. Wiley & Sons, (1982)

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	21 hrs	11 hrs	0 hrs	0 hrs	0 hrs

Aircraft design and construction [CAE]

LEAD PROFESSOR(S): Laurent GORNET / Laurent PERRET

Requirements

Objectives

The goal of the first part of the course is to provide the basic regulation on the main categories of aircraft, to define the methods of load calculation applied to aircraft (wing, tail plane and fuselage). In the second part, the lecture is based on the metallic and composite materials used in the airframes and the specific processes for the manufacture and assembly of the main components.

Course contents

- Aircraft history,
- Design principles,
- Design loads on aircraft: flight and landing.
- Sizing methods applicable on wing, tail planes and fuselage .
- Metallic and composite Materials used in the airframes
- Manufacturing and assembly processes of the main parts .

Course material

- Résistance des Matériaux appliquée à l'aviation, P. Vallat.
- Calcul des structures d'avions - cours ECP, F. Delisée.
- Aérodynamique - cours ENSAE, P. Rebuffet.
- Le projet d'avion léger, L. de Goncourt.
- Les secrets de la construction des aéronefs légers, M. Fékété.
- Design of Light aircraft (Richard D Hiscocks)
- Aircraft Structures (David J.Peery)

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	12 hrs	0 hrs	20 hrs	0 hrs	0 hrs

Project 2 [P2AERO]

LEAD PROFESSOR(S): Guy CAPDEVILLE

Requirements

Objectives

Study and carry out a technical project dealing with aeronautics in order to consolidate knowledge acquired in the specialisation.

Course contents

Examples of previous projects undertaken:
- Modelling of winglets' on the Onera-M6 wing
- Rocket simulation
- Study of the design of ultra-light aircraft
- Study of a ramjet engine
- Aero-elastic behaviour of airfoils and flaps
- Aerodynamic design of a drone
- Flight simulation of a hypersonic vehicle

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	2	0 hrs	0 hrs	0 hrs	48 hrs	0 hrs

ENGINEERING - OD AERONAUTIQUE

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

Computational aerodynamics [SAE]

LEAD PROFESSOR(S): Boris CONAN / Guy CAPDEVILLE / Laurent PERRET

Requirements

Objectives

- Computation of classical problem in aerodynamics using specific software.
- Use of theories and models developed in the other courses of the Aeronautics specialisation
- Comparisons between different numerical models.
- Comparisons of numerical results with theory and experience.

Course contents

- Technical methods for generating structured/unstructured meshes.
- Modelling of a supersonic jet in a converging-diverging nozzle.
- Turbulence modelling: turbulent boundary-layer, the backward facing step.
- Supersonic turbojet inlet - diffraction of a shock wave.
- Boundary-layer shock wave interaction.
- Noise generated by a fluid flow.
- Numerical simulation of a transsonic flow around a NACA airfoil.

Course material

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	6 hrs	16 hrs	10 hrs	0 hrs	0 hrs

ENGINEERING - OD AERONAUTIQUE

Year 2 / Year 3 - Spring Semester - Course Unit 103 / 83

Passive safety of aeronautic structures [SPSAE]

LEAD PROFESSOR(S): Patrick ROZYCKI

Requirements

Finite Element Method, Constitutive behaviour law, Plasticity

Objectives

Industrial safety issues, particularly in the area of transportation, require increasingly precise knowledge of the behaviour of materials and structures submitted to rapid dynamic loading.

This course aims to examine current practices and future trends in this field, with regard to mechanical, numerical and experimental aspects. The main concepts covered are: materials modelling for dynamic loading (constitutive laws, strain rate sensitivity, experimental characterisation methods), crash design rules, numerical simulation (tools and integration schemes for a model), and experimental methods to characterise structure behaviour.

Through these concepts the students will be able to identify the links between numerical model creation and experimental conditions. They will be able to address the different issues in each of these tools. This can only strengthen their critical sense and increase their capacity to propose the best numerical/experimental correlations.

To consolidate the learning process the students will undertake a project: first, they will carry out a crushing test. Then, they will have to provide a numerical model of the experiment. Finally, they will have to analyse the results and highlight the various problems at each step.

Course contents

1. Overview of shocks
  - Nature, type and classification of shocks

2 Crash in the field of transportation
  - Overview, safety, different approaches used etc.

3. Numerical modelling
  - Constitutive laws, different time integration methods, non-linearities

4. Experimental devices
  - Description, different types of tests (front or side-impact) etc.

5 Study of an analytical model for circular or square tubes

6 Simple case study
  - Experiment on a simple structure, numerical simulation and experimental/numerical correlations

Course material

N. Jones, Structural Crashworthiness, Cambridge University Press, 1997

Jorge A.C. Ambrósio, Manuel F.O. Seabra Pereira, F. Pina da Silva, Crashworthiness of Transportation Systems: Structural Impact and Occupant, Springer Netherlands, 1997

Assessment

Collective assessment: EVC 1 (coefficient 1.0)

LANGUAGE OF INSTRUCTION	ECTS CREDITS	LECTURES	TUTORIALS	LAB	PROJECT	EXAM
French	3	4 hrs	0 hrs	28 hrs	0 hrs	0 hrs