Universidad Politécnica de Cartagena

Centro Universitario de la Defensa

Fundamentals of Flight I (Aerodynamics)
Syllabus

Industrial Organization Engineering Degree

Academic year 2012-2013

1. Course details

Name	Fundamentals of Flight I (Aerodynamics)				
Course field	Aerodynamics and Flight Mechanics				
Code	511103012				
Degree Course	Industrial Organization Engineering Degree				
Programme	2009 (Decreto 269/2009 de 31 de julio)				
Faculty	Centro Universitario de la Defensa en la Academia General del Aire				
Type	Optional (Flight specialty)				
Duration	Four-month course			**Year**	3rd
Language	Spanish				
ECTS	6	**Hours / ECTS**	25	**Total workload (hours)**	150
Lectures Timetable	Tuesday and Thursday 16:05-17:50			**Room**	To be defined
Classes/Practicals/Seminars timetable	Two sessions in APNC hours			**Building**	Classrooms

2. Teaching Staff contact details

Head of the course	José Serna Serrano		
Department	Integration		
Area of expertise	Aerospace Engineering		
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Office hours location (for supervisions)	Room 28 @ CUD building		

3. Course outline

3.1. Presentation

The special features of the Centro Universitario de la Defensa (CUD) placed at the Spanish Air Force Academy (AGA) cause the offered Industrial Organization Engineering Degree must complete the general curriculum of this Degree with specific subjects related to the environment in which former students will develop their professional activity.

Two specific characteristics will define this environment. On the one hand, life and military values, for which students receive specific training during their studies. On the other hand, the aeronautical character of their profession. This last fact raises the need to complete the practical training received, with a theoretical one that enable students to learn the basics and the particular problems that appears in the complex aviation environment.

The course "Fundamentals of Flight I (Aerodynamics)" is an optional subject in the academic conception of the curriculum, recommended for those students of the Flight specialty. The aim of the course is the students learn the theoretical fundamentals of aircrafts atmospheric flight. Previously acquired knowledge on Fluid Mechanics and Rigid Body Mechanics are applied to the particular case of aerodynes and especially to fixed-wing aircraft. Thus, this subject develops a synthesis and application of the student's background that will provide him enough theoretical knowledge to interpret certain phenomena that appear in the practical development of their profession.

The course is temporary placed in the curriculum as the ideal complement to the Flight Training the student begins to perform during his third year at the AGA. The complex and practical character of the subject will also develop skills such as teamwork, independent learning and the adoption of critical attitudes to technical problems.

3.2. Year and duration within the degree programme

The subject "Fundamentals of Flight I (Aerodynamics)" is studied at the Third Year of the Industrial Organization Engineering Degree.

3.3. Description of the course

The course is conceived with three different parts.

The first part covers the Basic Aerodynamics subject. Starting from the equations governing the fluids motion, and after appropriate simplifications, they are applied to the calculation of forces and moments on aerodynamic bodies. The complexity of the problems will be increased with the course evolution. After an introduction of the fundamental solutions of potential flows, the Kutta condition and the aerodynamic coefficients definitions, the study of 2D profiles in incompressible regime will be undertaken, explaining the role of the thickness, curvature and angle of attack in the aerodynamic behavior. Then, the incompressible flow study is extended to three-dimensional bodies highlighting the wingspan effect and justifying the existence of optimal wing planforms. The introduction of compressibility phenomena will expand the study to profiles and wing in high subsonic and supersonic regimes. To complete this part, the viscous phenomena are explained, developing the concept of boundary layer and its implications for the drag force and critical phenomena such as stall and spin. With the theory developed so far, students will be able to understand the operation of lift devices and justify their existence on the aircraft.

The second part of the course will consist of a brief description and study of the generation of propulsive forces on aircrafts. Two types of powerplants are studied: the reciprocating engine propeller assembly, and jet engines. Simple models will be developed for the study of the basic performances of these elements, mainly their behavior with altitude. The powerplants were deeply studied at the second course subject “Energetic Technology”, thus in this course only a brief summary is done, explaining with a bigger detail the propeller operation.

The third part of the course will be focused on the study of the Flight Mechanics. For this part, the aircraft will be considered as a rigid body with six degrees of freedom for the calculation of its position and attitude. Beginning with the general formulation and the forces acting on the airplane (studied in the first part of the course beside an Atmosphere model), representative cases of flight performances will be studied. The glider will be the first studied problem to focus the working methodology of this part. Then, performances (both integral and point performances) of the propeller-powered and jet-engine aircrafts will be studied. Among other results, the optimal endurance and range for these aircrafts will be derived (Breguet formulas). A simplified quantitative and qualitative study of longitudinal and lateral-directional stability and control will be done. Finally, an introduction to the rotary-wings aircrafts characteristic and performances will be shown, with applications to fixed point flight and helicopter horizontal flight.

3.4. Related courses. Prerequisites and recommendations

To successfully face the course, students should have knowledge of the following subjects:

- Physics (1st year): essentially block 1 (mechanical waves).
- Calculus (1st year): differential and integral calculus, differential equations and complex variable.
- Fluid Mechanics (2nd year): the whole course.
- Energetic Technology (2nd year): thermodynamic study and performance of aeroengines and reciprocating internal combustion engines.

It is recommended that the student follow the "Meteorology and communications phraseology" (4th year) course of for a better understanding of the influence of the atmosphere on the flight performances.

This course can assist to understand and justifies some of the content of the "Avionics and aircraft general knowledge" (4th year) course.

3.5. Special measures

Special measures will be adopted to allow the simultaneity of the course with military and aeronautics training activities. Specifically, working groups will be formed to promote the cooperative learning, promoting the learning track by scheduled tutorships and activities delivery.

4. Competences

4.1. Specific competences of the course

Knowledge of the theoretical fundamentals of basic Aerodynamics (profiles in incompressible regime (subsonic and supersonic) and large wings). Calculation of aerodynamic forces acting on an aerodynamic body. Formulation of the aircraft rigid-body mechanical problem and application to the study of performances in simple and representative cases. Analysis of the stability and control of aircrafts.

4.2. Generic and transversal competences

INSTRUMENTAL COMPETENCES

- ☒ T1.1 Analytical and summary skills
- ☒ T1.3 Oral and written communication skills in their mother tongue
- ☒ T1.5 Basic computer skills
- ☒ T1.7 Problem solving skills

PERSONAL COMPETENCES

- ☒ T2.2 Teamwork

SYSTEMIC COMPETENCES

- ☒ T3.1 Ability to apply theory to practice
- ☒ T3.2 Learning ability
- ☒ T3.7 Ability to work autonomously

4.3. General aims/ Degree specific competences

PROFESSIONAL COMPETENCES

- ☒ E2.7 Ability to understand and operate aircraft systems, to act as consultant to design them as well as to supervise and manage air operations

4.4. Learning objectives

The main objective of the course is the understanding of how the aerodynamic forces determine the flight dynamics and the role of the different variables involved in the flight phenomenon. To do this, at the end of the course, students should be able to:

- Understand the basic lift mechanisms on airfoils and quantitatively characterize them from the point of view of potential theory.
- Determine the impact of the wingspan on the modification of the lift from the profile case.
- Differentiate the aerodynamic behavior in subsonic and supersonic regime. Justify the wind planform and profiles in both regimes.
- Understand the boundary layer concept and its role in the generation of drag force and stall.
- Know the high-lift devices: morphology, physical fundamentals of operation, need and effects on the generation of lift and drag.
- Quantitatively analyze the flight altitude effect on the propulsive needs and

powerplants performances.

- Analyze basic performance problems (puntual and integrals) for fixed wing aircraft.
- Calculate flight ceilings and optimize endurance and range with simple models for the aerodynamic and propulsive forces. aircraft.
- Understand the problematic of the stability and control of aircrafts. Justify the existence of controls (ailerons and rudders) and understand how it works.
- Develop a simple model for the study of the rotary-wing aircrafts.
- Be critical with design and simulation issues on Aerodynamics and Flight Mechanics, being able to assess the technical complexity of these sciences, and, have a basic knowledge to critically analyze the data other professionals can provide.

5. Contents

5.1. Contents according to the Degree programme

Atmosphere. Fundamental equations of Fluid Dynamics. Origin of the Aerodynamic forces. Influence of the wing planform. High-lift devices. Aircraft Performances. Static and dynamic stability. Shockwaves.

5.2. Lectures programme

Lesson 0. International Standard Atmosphere (review)

PART I. AERODYNAMICS.

D.U. 1. FLUID DYNAMICS REVISION. GENERAL CONCEPTS.

Lesson 1. Introduction. Review of fundamental concepts of fluid dynamics. Aerodynamics coefficients definitions.

Lesson 2. Ideal two-dimensional incompressible fluid flow. Fundamental solutions. The Kutta-Jukowsky theorem.

D.U. 2. INCOMPRESSIBLE TWO DIMENSIONAL IDEAL AERODYNAMICS.

Lesson 3. Potential incompressible flow over two-dimensional profiles.

D.U. 3. INCOMPRESSIBLE THREE DIMENSIONAL IDEAL AERODYNAMICS.

Lesson 4. Potential incompressible flow over finite wings.

D.U. 4. COMPRESSIBLE FLOW.

Lesson 5. Potential compressible flow. General concepts. Shock waves.

Lesson 6. Potential compressible flow over aerodynamic profiles and wings.

D.U. 5. VISCOUS FLOW.

Lesson 7. Viscous flow introduction. Boundary layers. Viscous drag. Stall.

Lesson 8. Full aeroplane drag.

Lesson 9. High-lift and flow control devices.

PART II. PROPULSION SYSTEMS.

D.U. 6. AIRCRAFT POWERPLANTS.

Lesson 10. Aircraft powerplants. Aircraft with internal combustion engine and prop. Aeroengines.

PART III. FLIGHT DYNAMICS.

D.U. 7. GENERAL CONCEPTS. FULL PROBLEM FORMULATION.

Lesson 11. Introduction to flight mechanics. Nomenclature. General formulation of the problema.

D.U. 8. AIRCRAFT PERFORMANCES.

Lesson 12. Glider performances.
Lesson 13. Performances of aircrafts (propeller propulsion).
Lesson 14. Performances of aircrafts (jet propulsion).
Lesson 15. Flight envelopes and maneuver diagrams.
D.U. 9. STABILITY AND CONTROL
Lesson 16. Introduction to stability and control problems.
Lesson 17. Longitudinal stability and control.
Lesson 18. Lateral and directional stability and control.
D.U. 10. ROTATORY WINGS AIRCRAFTS.
Lesson 19. Introduction to rotatory wings aircrafts. Helicopter basic performances.

5.3. Classes/Seminars/practicals/tutorials programme

Laboratory sessions:

The Flight practices the students must perform simultaneously with the course impose a high time constraint. Such practices are considered to be the best practical materialization of the course contents. Thus, laboratory practices involving a high temporal dedication for students are not considered. Even so, two theoretical and practical sessions are planned to put the students in touch with the laboratory and computational work in Aerodynamics.

The learning objectives are:

- Make clear to students the difficulties encountered in the study of the real problems, when all simplifications that allow the existence of simple analytical models are eliminated.
- Understand the need for numerical simulations and experiments.
- Encourage student critical capacity, pointing out that the physical principles and simple models studied in lectures, should be used to judge the results of numerical simulations and experiments.
- Encourage the ability to implement the knowledge.
- Learn the main aspects of the laboratory work and the need for multidisciplinary teams to tackle complex problems.

The two considered practical sessions are:

Practice 1. Introduction to computational aerodynamics. Numerical simulations: the need, advantages and limitations.

Practice 2. Introduction to experimental aerodynamics. Aerodynamic tests and wind tunnel. Types of wind tunnels and obtainable data.

6. Teaching methodology

6.1. Learning activities			
Activity	**Lecturer role**	**Student role**	**ECTS**
Lectures	Explanation of the subject and following of students' acquisition and application. Doubts solution. Special attention on fundamental and most complex aspects will be made.	Attendance: attendance to classes and participation. Notes taking. Questions.	**1.2**
		Non-attendance: individual subject study.	**1.5**
Classes	Typical problems resolution and practical cases study with teacher assistance.	Attendance: active attendance . Questions and problems resolution.	**0.94**
		Non-attendance: individual subject study. Proposed problems resolution.	**1.1**
Practicals (laboratory classes)	Explanation, manage and direction of laboratory classes and computer lab.	Attendance Active participation. Notes taking. Questions and practice performance.	**0.16**
		Non-attendance Reports writing.	**0.1**
Continuous assessment	Short theoretical-practical questions will be given to the student to be solved in the classroom as a technique to monitor the learning process.	Attendance Theoretical-practical problems solution.	**0.38**
Individual/Group proposed problems	Problems will be proposed to the students as a way to promote the cooperative work and to monitor the practical acquisition of knowledge.	Non-attendance Resolution of the proposed problems in reduced groups.	**0.32**
Supervisions and group tutorials	Proposed problems revision and students' doubts resolution.	Attendance Face theoretical and practical doubts. Non-attendance Theoretical and practical doubts via e-mail and virtual classroom.	**0.1**
Course assessment	An individual, partial written examination about the first part of the course will take place at the middle of the term. At the end of the term, a final individual written examination will be done.	Attendance. Written assessment attendance and solution.	**0.2**
TOTAL			**6**

7. Assessment

7.1. Assessment system			
Methods	**Criteria**	**Weighting**	**Generic competences**
Individual written examination (70%) (1)	**Theoretical and theoretical-practical questions:** An examination with 4 short theoretical or theoretical-practical questions about fundamental concepts will be made. Mainly, the theoretical knowledge is evaluated.	40 % Of the exam	T1.1, T1.3, T1.7, T3.1, T3.2, T3.7
	Problems: It will consist in 1 or 2 medium-long duration problems. Mainly, the practical application of the acquired knowledge and the analysis capacity are evaluated.	60 % Of the exam	T1.1, T1.3, T1.7, T3.1, T3.2, T3.7

Continuous assessment (10%) (2)	Eventually, short problems and questions will be given to be solved at the classroom as a way to continue monitoring the students evolution.	Depending on the number and difficulty of the proposed assessments.	T1.1, T1.2, T1.3, T1.7, T3.1, T3.2, T3.7
Individual/Group proposed problems (20%)	4 problems will be proposed along the course to be solved by reduced students groups.	25 % each proposed problem.	T1.1, T1.2, T1.3, T1.5, T2.1 T1.7, T3.1, T3.2, T3.7

(1) There will be an individual written examination (IWE) at mid-term, which will focus on the first part of the course (Aerodynamics [Lessons 0-9]). The students that obtain a global score greater than 4.5 on 10 will remove this part of the final examination.
The final examination will consist of two IWEs, firstly, all students will do the IWE corresponding to parts II (propulsion [Lesson 10]) and III (flight mechanics [Lessons 11-19]). After a break, the IWE corresponding to the first part [Lessons 0-9] will be done by those students who did not remove such material in the partial IWE, or those wishing to obtain a higher mark on that part. All students can do this second IWE, but, those who removed the contents in the partial IWE, if they give this part to the teacher will renounce to the mark obtained in the partial IWE.
The IWEs will follow the specifications previously detailed.

(2) Problems and questions will be given to be solved in the classroom during 45 minutes or an hour. The methodology may vary according to the characteristics of the lessons: multiple choice or test questions for those lessons with a lot of theoretical content; short problems of direct application of formulations or concepts; and even, medium-high difficulty problem guided by the professor for the more practical lessons.

The score the course (N) is calculated using the following expression:

$$0 < IWE < 4.5 \rightarrow N = IWE$$

$$4.5 \leq IWE \leq 5.0 \rightarrow N = \min(5.0, 0.7IWE+0.2PP+0.1CA)$$

$$IWE > 5 \rightarrow N = 0.7IWE + 0.2PP + 0.1CA$$

Being

IWE = arithmetic average of the individual written examinations (rated from 0 to 10).
PP = proposed problems score (rated from 0 to 10).
CA = continuous assessments score (rated from 0 to 10).

To pass the course it must be N ≥5.0.

7.2. Learning process monitoring

Monitoring will be done by some of the following mechanisms:
- Proposed class questions and cooperative learning activities (with problems).
- Monitoring and review of the proposed problems.
- Individual tutorials.
- Monitoring of the student activities.
- Individual partial written tests throughout the course.

8. Results, learning activities and assessment

8.1. Learning objectives/learning activities/results assessment

Learning objectives (4.4)	Lectures	Classes	Practicals	Tutorials	Continous assessment	Assessment	Problems
Understand the basic lift mechanisms on airfoils and quantitatively characterize them from the point of view of potential theory.	X	X		x	X	X	X
Determine the impact of the wingspan on the modification of the lift from the profile case.	X	X		X	X	X	X
Differentiate the aerodynamic behavior in subsonic and supersonic regime. Justify the wind planform and profiles in both regimes.	X	X	X	X	X	X	X
Understand the boundary layer concept and its role in the generation of drag force and stall.	X		X	X	X		
Know the high-lift devices: morphology, physical fundamentals of operation, need and effects on the generation of lift and drag.	X			X	X		
Quantitatively analyze the flight altitude effect on the propulsive needs and powerplants performances.	X	X		X	X	X	X
Analyze basic performance problems (puntual and integrals) for fixed wing aircraft.	X	X		X	X	X	X
Calculate flight ceilings and optimize endurance and range with simple models for the aerodynamic and propulsive forces. aircraft.	X	X		X	X	X	X
Understand the problematic of the stability and control of aircrafts. Justify the existence of controls (ailerons and rudders) and understand how it works.	X			X	X	X	
Develop a simple model for the study of the rotary-wing aircrafts.	X	X		X	x	X	X
Be critical with design and simulation issues on Aerodynamics and Flight Mechanics, being able to assess the technical complexity of these sciences, and, have a basic knowledge to critically analyze the data other professionals can provide.	x		x			x	

9. ECTS Allocation

COURSE		ATTENDANCE		CONVENTIONAL ATTENDANCE		NON-CONVENTIONAL ATTENDANCE		NON-ATTENDANCE	
CREDITS	TOTAL HOURS	AC	AH	CAC	CAH	NCAC	NCAH	NAC	NAH
6	150	2,93	73.25	2.3	57.5	0.63	15.75	3.07	76.75

AC: ATTENDANCE CREDITS
CAC: CONVENTIONAL ATTENDANCE CREDITS
NCAC: NON-CONVENTIONAL ATTENDANCE CREDITS
NAC: NON-ATTENDANCE CREDITS

AH: ATTENDANCE HOURS
CAH: CONVENTIONAL ATTENDANCE HOURS
NCAH: NON-CONVENTIONAL ATTENDANCE HOURS
NAH: NON-ATTENDANCE HOURS

10. SCHEDULE

		ATTENDANCE ACTIVITIES											NON-ATTENDANCE ACTIVITIES					
		Convencionales					No convencionales											
Week	Units	Lectures	Problems classes	Practical			Continuous assestement	Tutorials	Assestment				Self-study	Individual/Group proposed prolems	Practical Reports		TOTAL HOURS	DELIVERABLES
1	L0	0.75	0.5										1				2.25	
1	L1	0.75	0.5										1				2.25	
1	L2	1.5	1										3				5.5	
2	L3	1.5	1.5				0.75	0.5					3.5				7.75	
2-3	L4	2	2				1	0.5					5				10.5	
3-4	L5	2	1.5				1						4.5				9	
4-5	L6	1.5	1.5	2			0.75						4	2	1.25		11.75	
5	L7	1	1.5					0.5					3				6	
6	L8	1	2	2									5		1.25		10	PP1
6-7	L9	1.5					1						2				4.5	
7	PEI								2.5								2.5	
7	L10	3	2.5				1						6	2			14.5	
8	L11	1	1										2.5				4.5	
8-9	L12	1											1.5				2.5	PP2
9-10	L13	2.5	2.5										6				11	
10-11	L14	2.5	2.5				1						6				12	
12	L15	1	1										2	2			6	
12	L16	1											1.5				2.5	
13	L17	1.5	1				1						3	2			8.5	PP3
13-14	L18	1.5					1						1.5				4	
15	L19	1.5	1				1	1					3				7.5	
Exams									2.5									5
Other																		
Total hours		30	23.5	4	0	0	9.5	2.5	5	0	0	0	65	8	2.5	0	150	

L = Lesson

11. REFERENCES

GENERAL INTRODUCTORY TEXTS:

- Anderson, J.D. Jr. *Introduction to flight*. 7th edition. McGraw Hill. 2008.
- Carmona, A.I. *Aerodinámica y actuaciones del avión.* 12ª edición. Paraninfo. 2004.
- Franchini, S., López, O *Introducción a la Ingeniería Aeroespacial.* 2ª edición. Ed. Garceta 2011.

AERODYNAMICS:

- Anderson, J.D. *Fundamentals of aerodynamics* . 3rd edition. McGraw Hill. 2001.
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- Meseguer Ruiz, J., Sanz Andrés, A. *Aerodinámica Básica.* Publicaciones de la E.T.S.I. Aeronáuticos. Universidad Politécnica de Madrid. 2005.
- Abbot, I.H., Von Doenhoff, A.E. *Theory of wing sections*. Dover Publications Inc. 1949.
- Katz, J., Plotkin, A. *Low-speed aerodynamics.* Cambridge Aerospace Series.
- Anderson, J.D. Jr. *A History of Aerodynamics*. Ed. Cambridge University Press.

PROPULSION:

- “Energetic Technology” notes.

FLIGHT MECHANICS:

- Gomez Tierno, M.A. *Mecánica del Vuelo.* Publicaciones de la E.T.S.I. Aeronáuticos. Universidad Politécnica de Madrid. 2008.
- Ashley, H. *Engineering analysis of flight vehicles.* Addison – Wesley. 1974.
- Miele, A. *Flight mechanics – I. Theory of flight paths.* Addison – Wesley. 1962.