Universidad Politécnica de Cartagena

Centro Universitario de la Defensa

General Air Force Academy

Course unit description:

Fundamentals of Flight I (Aerodynamics)

Degree/s: Industrial Organization Engineering Degree

1. Subject data

Name	Fundamentals of Flight I (Aerodynamics)				
Subject area	Aerodynamics and Flight Mechanics				
Module	Optional Subject				
Code	511103012				
Degree programme	Industrial Organization Engineering Degree				
Curriculum	2009 (Decreto 269/2009 de 31 de julio)				
Centre	University Centre of Defense at the Spanish Air Force Academy				
Type	Optional (Flight specialty)				
Length of subject	Four-month course	**Semester**	2nd	**Course**	3th
Language	English				
ECTS 6	**Hours / ECTS** 25		**Total workload (hours)**	150	

2. Lecturer data

Lecturer in charge	José Serna Serrano		
Department	Engineering and Applied Techniques		
Knowledge area	Aerospace Engineering		
Office location	Room 28 @ CUD building		
Telephone	+34.968.189927	**Fax**	+34.968188780
email	jose.serna@cud.upct.es		
URL / WEB	Aula Virtual UPCT		
Office hours	Tuesday, Wednesday 12:50 – 14:35		
Location	Room 28 @ CUD building / Virtual classroom		

Qualification/Degree	Aeronautical Engineer. Ph.D. at the Universidad Politécnica de Madrid. (Aerospace Science and Technology Program)
Academic rank at CUD-UPCT	Assistant Professor (Tenure Track) at Associate Center
Year of admission in CUD-UPCT	2012
Number of five-year periods (*quinquenios*) if applicable	1
Research lines (if applicable)	* Experimental Aerodynamics: facilities design, instrumentation and experimental tests. * Boundary layer stability and control: experimental and numerical researches. * Aerodynamic profiles for “low” Reynolds numbers aerodynamics. * Heat Transfer Applications.
Number of six-year periods (*sexenios*) if applicable	1
Professional experience (if applicable)	* Fluid Mechanics Laboratory. School of Aeronautics. UPM (basic and industrial research) > 7 years. * BBVA (Quantitative developer at front desk: equity and FX derivatives valuation). 1 year.
Other topics of interest	UAVs: technology and integration in the air space.

Lecturer	Alejandro López Belchí		
Department	Engineering and Applied Techniques		
Knowledge area	Heat Engines		
Office location	Room 31 @ CUD building		
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URL / WEB	Aula Virtual UPCT		
Office hours	Tuesday, Thursday 12:50 – 14:35		
Location	Room 28 @ CUD building / Virtual classroom		

Qualification/Degree	Mechanical Engineer. Ph.D. at the Universidad Politécnica de Cartagena
Academic rank at CUD-UPCT	Assistant Professor at Associate Center
Year of admission in CUD-UPCT	2015
Number of five-year periods (*quinquenios*) if applicable	0
Research lines (if applicable)	* Two-phase flow heat transfer * High efficiency cooling systems * Heat engines
Number of six-year periods (*sexenios*) if applicable	0
Professional experience (if applicable)	Thermal modelling and energetic systems. ETSII. UPCT (4years)
Other topics of interest	Experimental Aerodynamics

3. Subject description

3.1. General description

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

Particularly, the aeronautical environment raises the need to teach the students the theoretical background that enable them to learn the basics and the particular problems that appears in this complex 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 immediate 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. How the subject contributes to a professional career

The subject contents correlate to the 080 block of the JAR syllabus for obtaining Flight Crew Licenses. During the course the main concepts for this block are widely explained both from the practical and engineering points of view, thanks to the physical-mathematical background of students. This focus will allow the student a deeper knowledge and the ability to deduce most of the JAR contents.

3.3. Relationship with other subjects in the programme

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.

3.4. Incompatibilities defined in the programme

No incompatibilities have been defined

3.5. Recommendations to do the subject

See section 3.3

3.6. Special provisions

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 and learning outcomes

4.1. Basic curricular competences related to the subject
KC5. Students must have developed the learning abilities needed to undertake subsequent studies with a high degree of autonomy.

4.2. General curricular competences related to the subject
GC2. Application of general technologies and fundamental subjects in the industrial domain for the solving of engineering problems.

4.3. Specific curricular competences related to the subject
SC30. Analyze topics applied to engineering and aircraft systems operations.

4.4. Transversal curricular competences related to the subject
CCC3. Autonomous learning

4.5. Subject learning outcomes

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:

1. Understand the basic lift mechanisms on airfoils and quantitatively characterize them from the point of view of potential theory.
2. Determine the impact of the wingspan on the modification of the lift from the profile case.
3. Differentiate the aerodynamic behavior in subsonic and supersonic regime. Justify the wind planform and profiles in both regimes.
4. Understand the boundary layer concept and its role in the generation of drag force and stall.
5. Know the high-lift devices: morphology, physical fundamentals of operation, need and effects on the generation of lift and drag.
6. Quantitatively analyze the flight altitude effect on the propulsive needs and powerplants performances.
7. Analyze basic performance problems (puntual and integrals) for fixed wing aircraft.
8. Calculate flight ceilings and optimize endurance and range with simple models for the aerodynamic and propulsive forces. aircraft.
9. Understand the problematic of the stability and control of aircrafts. Justify the existence of controls (ailerons and rudders) and understand how it works.
10. 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. Curricular contents related to the subject

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. Theory syllabus (teaching modules and units)

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.

5.3. Practice syllabus (name and description of every practical)

Laboratory sessions:

AIRFOIL AERODYNAMICS. At the Wind Tunnel at UDITA, the students will be introduced to research works in experimental aerodynamics with a 2 hours laboratory session.
The practice will be carried out in class hours due to the schedule limitation in 3rd course. Only 2/3 students will be at the same time in the laboratory in order to take the maximum advantage of the time there. This reduced number of students will allow the use by themselves of the facility and the experimental techniques with the continuous supervision of the professor.
The practice session will deal about airfoil aerodynamics, making use of flow visualizations, pressure measurements and other fluid-dynamics diagnostic techqniques.

NOZZLE FLOW. The students will perform measurements of the pressure at several stations of a convergent-divergent nozzle for different stagnation pressures. The experimental results will be compared with the theory explained during lectures. To do this work, the group will be divided into 2 subgroups, during 1 hour each subgroup will perform the experimental task, while the other subgroup will do a continuous assessment problem about compressible flow.

Risk prevention

Promoting the continuous improvement of working and study conditions of the entire university community is one the basic principles and goals of the Universidad Politécnica de Cartagena.

Such commitment to prevention and the responsibilities arising from it concern all realms of the university: governing bodies, management team, teaching and research staff, administrative and service staff and students.

The UPCT Service of Occupational Hazards (*Servicio de Prevención de Riesgos Laborales de la UPCT*) has published a "Risk Prevention Manual for new students" (*Manual de acogida al estudiante en materia de prevención de riesgos*), which may be downloaded from the e-learning platform ("Aula Virtual"), with instructions and recommendations on how to act properly, from the point of view of prevention (safety, ergonomics, etc.), when developing any type of activity at the University. You will also find recommendations on how to proceed in an emergency or if an incident occurs.

Particularly when carrying out training practices in laboratories, workshops or field work, you must follow all your teacher's instructions, because he/she is the person responsible for your safety and health during practice performance. Feel free to ask any questions you may have and do not put your safety or that of your classmates at risk.

5.4. Theory syllabus in english (teaching modules and units)

See Section 5.2.

5.5. Detailed description of learning goals for every teaching module

The learning goals (identified by their number in Section 4.5) are related to the teaching modules according to the following scheme:

D.U. 1. FLUID DYNAMICS REVISION. GENERAL CONCEPTS.
Learning goals 1, 3, 4

D.U. 2. INCOMPRESSIBLE TWO DIMENSIONAL IDEAL AERODYNAMICS.
Learning goals 1, 3, 10

D.U. 3. INCOMPRESSIBLE THREE DIMENSIONAL IDEAL AERODYNAMICS.
Learning goals 1, 2, 3, 10
D.U. 4. COMPRESSIBLE FLOW.
Learning goals 1, 2, 3, 10
D.U. 5. VISCOUS FLOW.
Learning goals 4, 5, 10
D.U. 6. AIRCRAFT POWERPLANTS.
Learning goals 6, 10
D.U. 7. GENERAL CONCEPTS. FULL PROBLEM FORMULATION.
Learning goals 6, 7, 8, 9, 10
D.U. 8. AIRCRAFT PERFORMANCES.
Learning goals 6, 7, 8, 10
D.U. 9. STABILITY AND CONTROL.
Learning goals 9, 10

6. Teaching method

6.1. Teaching method

Teaching activity	Teaching techniques	Student workload	Hours
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.	**30**
		Non-attendance: individual subject study.	**37**
Practices	Explanation of the measurement techniques and the measurement chain. Trainee in the data acquisition and postprocessing techniques	Attendance: Attendance and active practical work	**3**
		Non-attendance: Data postprocessing and report generation	**6**
Classes	Typical problems resolution and practical cases study with teacher assistance.	Attendance: active attendance . Questions and problems resolution.	**25.5**
		Non-attendance: individual subject study. Proposed problems resolution.	**31.5**
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.	**9.5**
Supervisions and group tutorials	Proposed problems revision and students' doubts resolution.	Attendance Face theoretical and practical doubts.	**2.5**
		Non-attendance Theoretical and practical doubts via e-mail and virtual classroom.	
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.	**5**
TOTAL			150

6.2. Learning outcomes (4.5) / teaching activities (6.1)

	Learning outcomes									
Teaching activities (6.1)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Lectures	X	X	X	X	X	X	X	X	X	X
Practices	X	X		X						X
Classes	X	X	X			X	X	X		
Continuous assessment	X	X	X	X	X	X	X	X	X	
Supervisions and group tutorials	X	X	X	X	X	X	X	X	X	
Course assessment	X	X	X	X	X	X	X	X	X	X

7. Assessment method

7.1 Assessment method

Assesment activity	Type		Assessment methods and criteria	Percentage (%)	Assessed learning outcomes (4.5)
	Summative	Formative			
Individual Written Assessment (1)	X	X	**Theoretical and theoretical-practical questions:** An examination with test questions similar to the JAR examinations and/or short theoretical or theoretical-practical questions about fundamental concepts will be made. Mainly, the theoretical knowledge is evaluated.	32%	1 a 10
	X	X	**Problems:** It will consist in some medium duration problems. Mainly, the practical application of the acquired knowledge and the analysis capacity are evaluated.	48%	1 a 10
Continuous Assessment (2)	X	X	Eventually, short problems and questions will be given to be solved at the classroom as a way to continue monitoring the students evolution.	10%	1 a 10
Practices (3)	X	X	The correct performance of the experimental tasks, according to the teacher's instruction, will be evaluated. Additionally, the students must answer some questions about the fundamentals and practical features of the practical work.	10%	1 a 10

COMMENTS:

(1) There will be an individual written examination (IWE1) 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 be exempted to be evaluated again of this part at the final examination.
The final examination will consist of two IWEs, firstly, all students will do the IWE2 corresponding to parts II (propulsion [Lesson 10]) and III (flight mechanics [Lessons 11-18]). After a break, the IWE1 corresponding to the first part [Lessons 0-9] will be done by those students who did not rid such material in the partial IWE1, or those wishing to obtain a higher mark on that part. All students can do this second IWE1, but, those who rid the contents in the partial IWE1, if they give this part to the teacher, will renounce to the mark obtained in the partial IWE1.
The IWEs will follow the specifications previously detailed.
To pass the course it is necessary but not enough to obtain a minimum mark of 4.5 at each of the

IWEs. If this condition is not satisfied, the student will not pass the whole course, being the maximum mark in this situation 4.5. To clarify this point, let's suppose that a student gets the following marks: IWE1 = 3.0, IWE2 = 10.0, the average mark is IWE = 6.5, but as long as IWE1 is lower than 4.0, the final mark of the student will be 4.5.

Additionally considerations on IWEs:

1. If the student's handwriting is illegible, the student will fail the IWE with a maximum qualification of 4.0.
2. If the student doesn't write correctly his name in every sheet he gives to the teacher, the student will fail the IWE with a maximum qualification of 4.0.
3. The student can have on the desk, only the material allowed by the teacher in any moment.
4. Additional considerations can be made on particular IWEs calls.

(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.

(3) The methodology of each practical session will be explained by the lecturer at the laboratory.

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

$$\text{If} \left\{ \begin{matrix} IWE_1 \geq 4.5 \\ IWE_2 \geq 4.5 \end{matrix} \right\} \Rightarrow IWE = \frac{IWE_1 + IWE_2}{2} \left\{ \begin{matrix} 0 \leq IWE < 4.5 & \Rightarrow & N = IWE \\ 4.5 \leq IWE < 5.0 & \Rightarrow & N = \min(5.0, 0.2IWE + 0.1PP + 0. \\ 5.0 \leq IWE \leq 10.0 & \Rightarrow & N = 0.8IWE + 0.1PP + 0.1CA \end{matrix} \right.$$

Otherwise N = min(4.5,IWE)

Being

IWE = arithmetic average of the individual written examinations (rated from 0 to 10).

PP = practical work 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. Control and monitoring methods (optional)

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. Bibliography and resources

8.1. Basic bibliography

GENERAL INTRODUCTORY TEXTS:

- Anderson, J.D. Jr. *Introduction to flight*. 7th edition. McGraw Hill. 2008.
  ISBN 978-007-108605-9
- Carmona, A.I. *Aerodinámica y actuaciones del avión.* 12ª edición. Paraninfo. 2004.
  ISBN 9788428326407
- Franchini, S., López, O *Introducción a la Ingeniería Aeroespacial.* 2ª edición. Ed. Garceta 2011.
  ISBN 978-84-9281-290-5

8.2. Supplementary bibliography

AERODYNAMICS:

- Anderson, J.D. *Fundamentals of aerodynamics* . 3rd edition. McGraw Hill. 2001.
- Houghton, E.L. y Carpenter, P.W. *Aerodynamics for Engineering Students.* 5th Edition.
- 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.

8.3. On-line resources and others

Virtual Classroom
Class slideshows