Course guide
220301 - 220301 - Aerodynamics, Flight Mechanics and Orbital Mechanics

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Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 220 - ETSEIAT - Terrassa School of Industrial and Aeronautical Engineering.

Degree: MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Compulsory subject).

Academic year: 2024 **ECTS Credits:** 7.5 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: Josep Oriol Lizandra i Dalmases

Others: Manel Soria Guerrero
Jaume Calaf Zayas

PRIOR SKILLS

The same as those that the student is supposed to have demonstrated in the previous degree that has given him/her access to the MUEA, in accordance with the regulations established by the UPC.

REQUIREMENTS

Since it is a first year subject, no specific requirements are defined, except for those subjects that the student is supposed to have already taken in the previous degree that has given him / her access to the MUEA, in accordance with the regulations established by the UPC.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE03. MUEA/MASE: Understanding and mastery of external aerodynamics laws in different flight regimes and the application of these laws to numerical and experimental aerodynamics.
CE05. MUEA:MASE: Understanding and mastery of atmospheric flight mechanics (performance and static and dynamic stability and control), orbital mechanics and attitude dynamics.
CG09-MUEA. (ENG) Competència en totes aquelles àrees relacionades amb les tecnologies aeroportuàries, aeronàutiques o espacials que, per la seva naturalesa, no siguin exclusives d'altres branques de l'enginyeria.
CE12. MUEA/MASE: Sufficient knowledge of advanced fluid mechanics, particularly experimental and numerical techniques used in fluid mechanics.

Basic:
CB06. Manage original concepts in research projects.
CB08. Generate decision from incomplete information assuming its social and ethical responsibilities.
CB10. Improve self-learning capacity
CB09. Improve technical communication of results.

TEACHING METHODOLOGY

The teaching methodology is divided into three parts:
- Face-to-face exhibition sessions - participation of the contents and realization of exercises.
- Face-to-face laboratory work sessions.
- Autonomous work of study and realization of exercises and activities.

In the exhibition sessions -participation of the contents, the teacher will introduce the theoretical bases of the subject, concepts, methods and results illustrating them with convenient examples and requesting, if necessary, the realization of exercises to facilitatene their understanding.

In the laboratory work sessions, the teacher will guide the students in the application of the theoretical concepts for the resolution of exercises, basing at all times the critical reasoning.

The student, autonomously, must work on the material provided by the teachers and the result of the work-problem sessions in order to assimilate and fix the concepts. Teachers will provide a study and activity monitoring plan (ATENEA).

LEARNING OBJECTIVES OF THE SUBJECT

At the end of the course the student must:
- To know the basic numerical techniques for the calculation of non-viscous and incompressible flows around profiles and wings.
- To know the techniques used in experimental aerodynamics.
- Understand how the effects of compressibility of air at high flight speeds influence the aerodynamics and operation of the aircraft engine.
- To see that interesting qualitative (and to some extent, also quantitative) results can be obtained from the dynamic behavior of the plane, posing linearized differential equations, considering the small perturbations with respect to a stationary motion reference state.
- Understand that, under the hypotheses of linearization, the longitudinal movement can be decoupled from the lateral movement.
- Understand how the geometry, configuration and mass distribution of the aircraft affect the longitudinal and lateral stability derivatives of the aircraft.
- To know how to calculate the modes corresponding to the longitudinal and lateral free movement, and to understand how the derivatives of stability and other parameters of the airplane influence in the dynamic behavior of this one.
- To know how to apply classical control theory to flight dynamics problems, especially in particular the most common modes (piloting laws) used in commercial aircraft.
- Understand how the controller parameters affect the dynamic response of the aircraft, and that by choosing these parameters appropriately an optimal response can be obtained, taking into account various aspects, such as accuracy, speed and stability of the response, comfort, etc.
- To know the different celestial coordinate systems and the fundamental plans, as well as the different time scales.
- To master the aspects of Kepler's motion, the orbital elements and the calculation of ephemeris.
- To know the basic maneuvers for the changes of orbit of spacecraft around the Earth.
- Understand the basics of the patched conic procedure, and trips to the moon or interplanetary.

STUDY LOAD

Type	Hours	Percentage
Hours small group	22,5	12.00
Hours large group	45,0	24.00
Self study	120,0	64.00

Total learning time: 187.5 h

CONTENTS

Module 1: Introduction to numerical and experimental aerodynamics

Description:
Introduction to the numerical solution of Navier-Stokes equations:
- Revision of incompressible Navier-Stokes equations.
- Mathematical aspects relevant to their numerical solution.
- Validation and verification of CFD codes.
- Finite control volume method.
- Staggered mesh.
- Treatment of the terms adjective and diffusive.
- Treatment of the pressure-speed coupling.
- Temporal integration algorithms.
Potential aerodynamics:
- Review of definitions and concepts of aerodynamics of profiles and wings.
- Numerical techniques for profiles in incompressible regime: panel methods
- Numerical techniques for incompressible wings: support line and support surface.
- Aerodynamics of profiles and wings in high and supersonic subsonic regime.

Related activities:
Teamwork assignment/s and, possibly, also in the partial exam.

Full-or-part-time: 93h 40m
Theory classes: 22h 30m
Laboratory classes: 11h 10m
Self study : 60h

Module 2: Stability and dynamic response of aircraft.

Description:
Generalities:
- General equations of motion of the plane as a rigid solid.
- Linearization of the equations of motion, with respect to a reference condition.
- Separation of longitudinal and lateral movement.
Stability and dynamic control of longitudinal movement:
- Longitudinal stability derivatives.
- Dynamic stability of longitudinal free movement. Complete and approximate systems.
- Longitudinal dynamic response in open loop.
Stability and dynamic control of lateral movement:
- Derivatives of lateral-directional stability.
- Dynamic stability of lateral free movement. Complete and approximate systems.
- Lateral dynamic response in open loop.
Introduction to automatic flight:
- Longitudinal modes.
- Lateral modes.

Specific objectives:
N/A

Related activities:
Teamwork assignment and/or in the final exam.

Full-or-part-time: 46h 55m
Theory classes: 11h 15m
Laboratory classes: 5h 40m
Self study : 30h

Module 3: Orbital Mechanics

Description:
- Reference systems for space. Time scales.
- Kepler motion and orbital elements.
- Determination of orbits.
- Perturbations of the orbits.
- Satellites around the Earth.
- Basic orbital maneuvers.
- Trajectories on the Moon and interplanetary.

Related activities:
Teamwork assignment and, possibly, in the final exam.

Full-or-part-time: 46h 55m
Theory classes: 11h 15m
Laboratory classes: 5h 40m
Self study : 30h

ACTIVITIES

Theory

Full-or-part-time: 40h
Theory classes: 40h

Practices

Full-or-part-time: 22h 30m
Laboratory classes: 22h 30m

Activity 1: Partial exam

Description:
Short theoretical questions and / or test.

Specific objectives:
N/A

Material:
N/A

Delivery:
N/A

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

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Activity 2: Final exam

Description:
Short theoretical questions and/or test.

Specific objectives:
N/A

Material:
N/A

Delivery:
N/A

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Activity 3: Teamwork assignment

Description:
Related to the contents of module 1.

Specific objectives:
N/A

Material:
N/A

Delivery:
N/A

Full-or-part-time: 30h
Self study: 30h

Activity 4: Teamwork assignment.

Description:
Related with the contents of modules 1 and/or 3.

Specific objectives:
N/A

Material:
N/A

Delivery:
N/A

Full-or-part-time: 60h
Self study: 60h

Activity 5: Teamwork assignment

Description:
Related with the contents of module 3

Specific objectives:
N/A

Material:
N/A

Delivery:
N/A

Full-or-part-time: 30h
Self study: 30h

GRADING SYSTEM

The final grade will be calculated according to the following expression:

N_FINAL = 0.14 * NP1 + 0.14 * NP2 + 0.18 * NA1 + 0.36 * NA2 + 0.18 * NA3

Where NP1 and NP2 are the grades of the first and second part, respectively, and NA1, NA2, and NA3 correspond to the grades of each of the teamwork assignments..

EXAMINATION RULES.

N/A

BIBLIOGRAPHY

Basic:
- Anderson, John D. Fundamentals of aerodynamics. 5th ed. New York: McGraw-Hill, 2011. ISBN 9780073398105.
- Anderson, John D. Introduction to flight. 7th ed. New York: McGraw-Hill, 2012. ISBN 9780073380247.
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- Chobotov, Vladimir A. Orbital mechanics. 3rd ed. Reston, VA: American Institute of Aeronautics and Astronautics, 2002. ISBN 1563475375.
- Etkin, B.; Reid, Ll. D. Dynamics of flight: stability and control. 3rd ed. New York: John Wiley & Sons, 1996. ISBN 0471034185.

Complementary:
- Abzug, M. J.; Larrabee, E. E. Airplane stability and control: a history of the technologies that made aviation possible. 2nd ed. Cambridge: Cambridge University Press, 2002. ISBN 0521809924.
- Abzug, M. J. Computational flight dynamics. Reston: American Institute of Aeronautics and Astronautics, 1998. ISBN 1563472597.
- Miele, Angelo. Flight mechanics. Vol. 1, theory of flight paths. Reading, Massachusetts [etc]: Addison Wesley, 1962.