Course guide
19386 - A - Astrodynamics

Last modified: 09/06/2023

Unit in charge: Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 749 - MAT - Department of Mathematics.

Degree: MASTER'S DEGREE IN AEROSPACE SCIENCE AND TECHNOLOGY (Syllabus 2015). (Optional subject).
MASTER'S DEGREE IN AEROSPACE SCIENCE AND TECHNOLOGY (Syllabus 2021). (Optional subject).

Academic year: 2023 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Defined in the course webpage at the EETAC website

Others: Defined in the course webpage at the EETAC website

PRIOR SKILLS

Strong basis in calculus and linear algebra. Some knowledge on ordinary differential equations, mechanics and numerical computations is also advised.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE1 MAST21. Apply the scientific method to the study of the particular phenomenology of the aerospace environment.

Generical:
CG1 MAST. Identify and learn about the main R+D+i activities in the aerospace field that are currently carried out internationally in academia, industry and the largest space agencies..
CG2 MAST. Identify and apply the fundamental theoretical, experimental and numerical analyzes currently used in aerospace engineering.

Transversal:
CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

Basic:
CB6. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context.
CB7. Students will be able to apply the acquired knowledge and their ability to solve problems in new or little explored environments in broader (or multidisciplinary) contexts related to their study area.
CB9. Students will be able to communicate their conclusions and the knowledge and ultimate reasons that support them to specialized and non-specialized audiences in a clear and unambiguous manner.
CB10. Students will acquire learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

TEACHING METHODOLOGY

Master classes will be eventually supported by slides but most details and problem examples, when possible, will be addressed on the blackboard.
Students should work in both autonomous and cooperative way when solving exercises and developing projects. Many cases, examples and problems requiring a big amount a computational basis will be solved using Matlab/Octave codes. Students will be required to use and/or to develop new scripts and functions during the class, or during the exam, using their own laptops.

LEARNING OBJECTIVES OF THE SUBJECT

Having completed the subject in a satisfactory way, the student should be able to:
- Understand the main concepts associated with astrodynamics and orbital mission design.
- Provide qualitative and quantitative results for many kinds of problems related with orbit determination, orbital transfers, orbit perturbations,... in practical applications.
- Use some analytical techniques (series expansions, averaging properties, ...) for the analysis of problems related with celestial mechanics.
- Model dynamical systems in terms of vectorfieds, implement them in a computational form and numerically propagate trajectories accounting for accurate results.
- Compute orbit structures and dynamic building blocks in general dynamical systems.

STUDY LOAD

Type	Hours	Percentage
Self study	80,0	64.00
Hours large group	45,0	36.00

Total learning time: 125 h

CONTENTS

Introduction, General Concepts and Historical Perspective

Description:
- Orbits about the Earth. General notions
- Kepler's and Newtons laws
- Basic models of celestial mechanics
- Basic problems in astrodynamics
- High and low energy transfers english

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group

Full-or-part-time: 7h
Theory classes: 4h
Self study : 3h

Classical Models of Orbital Mechanics

Description:
- The N-body problem and the classical integrals
- The 2-Body Problem and the central force field problem
- Integrals of energy and angular momentum
- Equation of the trajectory
- Conic sections and the geometry of conics
- Patched conics and notions of interplanetary mission design

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP3: Problem solving, with student participation.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher
AFP6: Elaboration of cooperative works

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group
AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.

Full-or-part-time: 18h
Theory classes: 6h
Self study : 12h

Orbital Elements and the Measure of Time

Description:
- Reference systems
- From Cartesian state to orbital elements and vice-versa
- The Two Line Elements
- The case of the orbit of the Earth about the Sun
- The celestial sphere. Notions of Spherical Astronomy and Spherical Trigonometry.
- The measure of time. Historical problems.
- Current time standards

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP3: Problem solving, with student participation.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher
AFP6: Elaboration of cooperative works

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group
AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.

Full-or-part-time: 21h
Theory classes: 6h
Self study : 15h

Kepler's Equation and Orbit Determination

Description:
- Position and velocity as a function of time
- Changes between coordinate frames. Coriolis theorem.
- Kepler's equation
- Basic methods of orbit determination

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP3: Problem solving, with student participation.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher
AFP6: Elaboration of cooperative works

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group
AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.

Full-or-part-time: 14h
Theory classes: 4h
Self study : 10h

Orbital Maneuvers and Basic Transfers

Description:
- Station coordinates and basic geodesy concepts
- Basic orbital transfers and orbit adjustments

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP3: Problem solving, with student participation.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher
AFP6: Elaboration of cooperative works

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group
AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.

Full-or-part-time: 16h
Theory classes: 6h
Self study : 10h

Gravitational and Non-Gravitational Perturbations

Description:
- Orbital perturbations. Models
- Gauss and Lagrange palnetary equations
- Analysis of the J2 perturbation. Consequences and Applications.

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP3: Problem solving, with student participation.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher
AFP6: Elaboration of cooperative works

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group
AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.

Full-or-part-time: 14h
Theory classes: 6h
Self study : 8h

Dynamical Systems and Vectorfields

Description:
- The concept of a Dynamical System
- Trajectories in a vectorfield
- The initial value problem and orbit propagation
- Numerical computations

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP3: Problem solving, with student participation.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher
AFP6: Elaboration of cooperative works

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group
AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.

Full-or-part-time: 16h
Theory classes: 6h
Self study : 10h

The Restricted Three Body Problem and Libration Point Orbits

Description:
- Equations of motion
- Zero velocity curves
- Libration Points and their local analysis
- Libration Point orbits and Low energy transfers
- Numerical Computations

Related activities:
AFP1: Exposition of theoretical contents through lectures.
AFP3: Problem solving, with student participation.
AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher
AFP6: Elaboration of cooperative works

AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group
AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.

Full-or-part-time: 19h
Theory classes: 7h
Self study : 12h

GRADING SYSTEM

Defined in the course webpage at the EETAC website

BIBLIOGRAPHY

Basic:
- Bate, Roger R; Mueller, Donald D; White, Jerry E. Fundamentals of astrodynamics. New York: Dover, cop. 1971. ISBN 9780486600611.
- Battin, Richard H. An Introduction to the mathematics and methods of astrodynamics. Rev. ed. Virginia: American Institute of Aeronautics and Astronautics, 1999. ISBN 1563473429.
- Gómez, G. Dynamics and mission design near libration points. Singapore [etc.]: World Scientific, 2001. ISBN 9810242859.
- Vallado, David A; McClain, Wayne D. Fundamentals of astrodynamics and applications. 4a ed. Hawthorne: Microcosm Press, cop. 2013. ISBN 9781881883180.

Complementary:
- Gurzadian, G. A. Theory of interplanetary flights. Australia [et al.]: Gordon and Breach, 1996. ISBN 2884490744.
- Escobal, Pedro Ramon. Methods of orbit determination. Reprint with corrections. Malabar, FL: Krieger Pub. Co, 1976. ISBN 0882753193.
- Sidi, M. J. Spacecraft dynamics and control : a practical engineering approach. Cambridge: Cambridge University press, 1997. ISBN 0521550726.
- de Iaco Veris, Alessandro. Practical astrodynamics. Springer, 2018. ISBN 9783319622194.