Course guide
19386 - A - Astrodynamics

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: 2022    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:
CE3 MAST. (ENG) CE3: Aplicar los métodos numéricos para ingeniería aeroespacial con especial énfasis en sus aplicaciones, y en especial en la dinámica de fluidos.
CE6 MAST. (ENG) CE6: Realizar, presentar y defender ante un tribunal universitario un ejercicio original realizado individualmente, consistente en un estudio de investigación en el campo de la Ingeniería Aeroespacial, en el que se sintetizan las competencias adquiridas en las enseñanzas, adoptando los avances y novedades en este campo y aportando ideas novedosas.

General:
CG1 MAST. (ENG) CG1: Identificar y conocer las principales actividades de I+D+i en el campo aeroespacial que se llevan a cabo actualmente a nivel internacional en el ámbito académico, la industria y las mayores agencias espaciales.
CG2 MAST. (ENG) CG2: Identificar y aplicar los análisis teóricos, experimentales y numéricos fundamentales de uso actual en ingeniería aeroespacial.
CG3 MAST. (ENG) CG3: Identificar y gestionar, de forma consistente, los diferentes tipos de vehículos aeroespaciales y los aspectos tecnológicos, de diseño e implementación de cargas útiles para misiones científicas.
CG4 MAST. (ENG) CG4: Participar en un proyecto de I+D+i del ámbito aeroespacial aportando una visión y conocimientos novedosos asociados con las técnicas de uso más puntero en el campo.

Transversal:
CT1b. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding the mechanisms on which scientific research is based, as well as the mechanisms and instruments for transferring results among socio-economic agents involved in research, development and innovation processes.
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.
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.
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.
Basic:
CB6. (ENG) CB6 - Poseer y comprender conocimientos que aporten una base o oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación.
CB7. (ENG) CB7 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.
CB9. (ENG) CB9 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades.
CB10. (ENG) CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self study</td>
<td>80,0</td>
<td>64.00</td>
</tr>
<tr>
<td>Hours large group</td>
<td>45,0</td>
<td>36.00</td>
</tr>
</tbody>
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Total learning time: 125 h
### 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

**Related activities:**
- AFP1: Exposition of theoretical contents through lectures.
- AFPS: 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.
- AFPS: 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 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 planetary equations

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.
AFPS: 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.
AFPS: 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:

Complementary: