19386 - AER - Astrodynamics

Coordinating unit: 300 - EETAC - Castelldefels School of Telecommunications and Aerospace Engineering
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2018
Degree: Master's Degree in Aerospace Science and Technology (Syllabus 2015). (Teaching unit Optional)
Master's Degree in Aerospace Science and Technology (Syllabus 2009). (Teaching unit Optional)
Doctoral Degree in Aerospace Science and Technology (Syllabus 2007). (Teaching unit Optional)
ECTS credits: 5
Teaching languages: English

Teaching staff
Coordinator: 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

Basic:
CB6. (ENG) CB6 - Poseer y comprender conocimientos que aporten una base u 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.

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
19386 - AER - Astrodynamics

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 vectorfields, 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.

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 vectorfields, 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>Total learning time: 125h</th>
<th>Hours large group: 45h</th>
<th>36.00%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Hours medium group: 0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Hours small group: 0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Guided activities: 0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Self study: 80h</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
## Content

### Introduction, General Concepts and Historical Perspective

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Orbits about the Earth. General notions</td>
</tr>
<tr>
<td>- Kepler's and Newton's laws</td>
</tr>
<tr>
<td>- Basic models of celestial mechanics</td>
</tr>
<tr>
<td>- Basic problems in astrodynamics</td>
</tr>
<tr>
<td>- High and low energy transfers english</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Related activities:</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFP1: Exposition of theoretical contents through lectures.</td>
</tr>
<tr>
<td>AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher</td>
</tr>
<tr>
<td>AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group</td>
</tr>
</tbody>
</table>

**Learning time:** 7h  
Theory classes: 4h  
Self study: 3h

### Classical Models of Orbital Mechanics

<table>
<thead>
<tr>
<th>Description:</th>
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</thead>
<tbody>
<tr>
<td>- The N-body problem and the classical integrals</td>
</tr>
<tr>
<td>- The 2-Body Problem and the central force field problem</td>
</tr>
<tr>
<td>- Integrals of energy and angular momentum</td>
</tr>
<tr>
<td>- Equation of the trajectory</td>
</tr>
<tr>
<td>- Conic sections and the geometry of conics</td>
</tr>
<tr>
<td>- Patched conics and notions of interplanetary mission design</td>
</tr>
</tbody>
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<td>AFP1: Exposition of theoretical contents through lectures.</td>
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<tr>
<td>AFP3: Problem solving, with student participation.</td>
</tr>
<tr>
<td>AFP5: Discussion in the classroom of problems or articles, made by the students and moderated by the teacher</td>
</tr>
<tr>
<td>AFP6: Elaboration of cooperative works</td>
</tr>
<tr>
<td>AFN2: Realization of exercises and theoretical or practical works outside the classroom, individually or in a group</td>
</tr>
<tr>
<td>AFN3: Realization of projects proposed by teachers outside the classroom, individually or in groups.</td>
</tr>
</tbody>
</table>

**Learning time:** 18h  
Theory classes: 6h  
Self study: 12h
# Orbital Elements and the Measure of Time

**Learning time:** 21h  
Theory classes: 6h  
Self study: 15h

**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.

# Kepler's Equation and Orbit Determination

**Learning time:** 14h  
Theory classes: 4h  
Self study: 10h

**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.
<table>
<thead>
<tr>
<th>orbital maneuvers and basic transfers</th>
<th>learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td>theory classes: 6h</td>
<td>self study: 10h</td>
</tr>
</tbody>
</table>

**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

**related activities:**
- 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.

<table>
<thead>
<tr>
<th>gravitational and non-gravitational perturbations</th>
<th>learning time: 14h</th>
</tr>
</thead>
<tbody>
<tr>
<td>theory classes: 6h</td>
<td>self study: 8h</td>
</tr>
</tbody>
</table>

**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

**related activities:**
- 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.
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.

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
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Qualification system

Defined in the course webpage at the EETAC website
Bibliography

Basic:


Complementary:


