Last update: 05-10-2018

220334 - Space Propulsion

Coordinating unit: 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 220 - ETSEIAT - Terrassa School of Industrial and Aeronautical Engineering
Academic year: 2018
Degree: MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Teaching unit Optional)
MASTER'S DEGREE IN SPACE AND AERONAUTICAL ENGINEERING (Syllabus 2016). (Teaching unit Optional)
ECTS credits: 5 Teaching languages: English

Teaching staff

Coordinator: Lizandra Dalmases, Josep Oriol

Others: Mudarra López, Miguel
Soria Guerrero, Manel

Opening hours

Timetable: By agreement between teacher and student.

Prior skills

Previous concepts include a great variety of subjects and disciplines given in any bachelor's degree in aerospace engineering, in especial, thermal rockets, but also: compressible fluid mechanics, elements of orbital mechanics. electromagnetism and statistical mechanics.
Taking these basic concepts, the course on Space Propulsion develops most of the scientific formulations necessary for the correct understanding of the thrusters, including some concepts of theory of plasmas. Thus, this field doesn't constitute a previous requirement.

Degree competences to which the subject contributes

Specific:
CEEESPAC1. MUEA/MASE: Sufficient applied knowledge of the planning of space missions (specific competency for the specialisation in Space).
CEEESPAC2. MUEA/MASE: Advanced applied knowledge of orbital dynamics and space vehicle design (specific competency for the specialisation in Space).
CE10-MUEA. MUEA/MASE: Sufficient knowledge of aircraft and space vehicle subsystems.

CE16-MUEA. MUEA/MASE: Sufficient knowledge of air-breathing jet engines, gas turbines, rocket engines and turbomachines.
CE18-MUEA. MUEA/MASE: The ability to design, execute and analyse propulsion systems tests and carry out the systems' entire certification process.
CE19-MUEA. MUEA/MASE: Sufficient knowledge of the subsystems of aerospace vehicles' propulsion power plants.

Teaching methodology

Classroom theory sessions to teach concepts and developments, combined with applied exercises in class, or teamwork assignments.

Learning objectives of the subject

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This subject aims the student to be familiar with the different types of thrusters used in spacecraft, especially, satellites orbiting the Earth. Once coursed and passed the student should:
1. Be aware of the needs for, and be able of carrying out, a mission optimization, including the Flight Dynamics with low thrust, the computation of velocity increments for several typical missions, accounting for the limited available power of most thrusters, affecting the acceleration attainable by the spacecraft.
2. Know the physics, design and performance of Electrothermal engines (resistojet and arcjet).
3. Have an adequate knowledge on plasma physics, on which the principles of operation of some types of thrusters is based.
4. Have a comprehensive knowledge of thrusters based on plasma physics: Hall Effect thrusters, ion and MPD thrusters.
5. Have notions about the expansion of a plasma plume into the vacuum, and application to the interaction between motor and satellites.
6. Have an adequate knowledge on electrodispersion of conductive fluids, with application to colloidal thrusters and ionic thrusters with ions from liquid origin.
7. Have notions about test facilities and techniques for this type of engines.

Study load

Total learning time: 125h	Hours large group:	30h	24.00%
	Hours small group:	15h	12.00%
	Self study:	80h	64.00%

Content

Module 1: Mission Analysis	Learning time: 15h Theory classes: 4h Laboratory classes: 2h Self study : 9h

Description:
Computation of the optimum specific impulse as a function of the required maneuver time and the specific mass of the power system. Effects of non-idealities of the engine. Selection of the thrust time. Optimum mass distribution. Computation of the velocity increment for a spiral climb. Optimization of the specific impulse - time profile. Optimization of missions with change of plane. Other missions.

Related activities:
Exam and/or assignment

Specific objectives:
...

2. Chemical rockets.	Learning time: 14h Theory classes: 4h Laboratory classes: 1h Self study : 9h

Description:
Module 2: Chemical thrusters.

Related activities:
Exam and/or assignment

Specific objectives:
Hydrazine thrusters. Properties of hydrazine. General design. Performance as a function of the degree of decomposition of ammonia. Feeding subsystem, valves, tanks, heaters, etc.

Module 3: Electrothermal thrusters.	Learning time: 14h Theory classes: 3h Laboratory classes: 2h Self study : 9h

Description:
Thrusters using heated hydrazine. Arc jet thrusters. Thermal plasmas. Simplified model of an arc jet. Estimation of performances. Examples of existing thrusters.

Related activities:
Exam and/or assignment.

Specific objectives:
...

Module 4: Introduction to magnetized plasmas	Learning time: 14h Theory classes: 4h Laboratory classes: 1h Guided activities: 9h

Description:
Notions on low density magnetized plasmas. Concepts of shielding and electrostatic sheath. Ion flow into a negative sheath. Diffusion and mobility of electrons. Anomalous diffusion. Model of Bohm. Volumetric velocity of ionization and excitation.

Related activities:
Exam and/or assignment

Specific objectives:
...

Module 5: Ionic thrusters	Learning time: 14h Theory classes: 3h Laboratory classes: 2h Self study : 9h

Description:
Conceptual design of a Kauffman type ionic thruster. Limitation of extracted current: Child-Langmuir equation. Magnetic confinement of electrons. Ion balance, estimations of the degree of ionization and efficiency of utilization. Brophy's model: prediction of performance charts. Examples of current thrusters.

Related activities:
Exam and/or assignment.

Module 6: Hall thrusters	Learning time: 14h Theory classes: 3h Laboratory classes: 2h Self study : 9h

Description:
Conceptual design, general considerations. Production of thrust. Breakdown of the engine's efficiency. Plasma structure: experimental data and one-dimensional modelling. Smooth or step sonic transition. Estimation of important parameters. Multidimensional models. Particle in cell method. Estimation of useful life. Examples of current thrusters.

Module 7: Self-induced field MPD thrusters	Learning time: 12h Theory classes: 3h Laboratory classes: 1h Self study : 8h

Description:
Regime of operation. Density of Lorentz force. Electric work and dissipation. Magnetic diffusion. Magnetic Reynolds number. Simplified one-dimensional analysis. Existence of thin current layers, net dissipation and efficiency. Instability onset. Possibility of variable area.

Mòdul 8: Plasma plumes. Interaction plume-spacecraft.	Learning time: 8h Theory classes: 2h Laboratory classes: 1h Self study : 5h

Description:
Basic physics of a plasma plume into the vacuum. Far limit. Charge exchange due to collisions, effects on the ions distribution. Estimation. Other effects.

Module 9: Surface Electrostatics. Colloidal thrusters.	Learning time: 14h Theory classes: 3h Laboratory classes: 2h Self study : 9h

Description:
Charge distribution within a conductive liquid and on its surface. Relaxation time. Surface instability. Taylor cone. Model of Fernandez de la Mora for the emission of charged droplets. Propulsive application: the colloidal engine. Examples and performance. Ion emission: mixed regime and pure ionic. Experimental data. Propulsive applications.

Module 10: Test stands and techniques.	Learning time: 6h Theory classes: 1h Laboratory classes: 1h Self study : 4h

Description:
Need for vacuum, depending on the engine. Vacuum plants. Thrust scales, micro-scales. Plasma probes (Langmuir, Faraday, energy metering systems). Mass spectroscopy by flight time. Optical techniques.

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Qualification system

The global grade is computed with the formula:

N_glob = 0.8 * (N_1 + N_2) + 0.2 * N_ass

N_1 and N_2 are, respectively, the grades of the first and final exam.
N_ass is the grade of the team assignment.

All those students aiming at improving the grade N1 achieved in the first exam or that were not able to attend it on the indicated date, will have another opportunity the same day of the final exam or another close date.

The new grade will replace the old one in any case, except in the following cases:

- If the old grade is higher or equal than 5, and the new grade is lower than 5, the grade for N1 will be 5.
- If the old grade is lower than 5 but higher or equal than 4, and the new grade is lower than 4, the grade for N1 will be 4.

For those students who meet the requirements and submit to the reevaluation examination, the grade of the reevaluation exam will replace the grades of all the on-site written evaluation acts (tests, midterm and final exams) and the grades obtained during the course for lab practices, works, projects and presentations will be kept.
If the final grade after reevaluation is lower than 5.0, it will replace the initial one only if it is higher. If the final grade after reevaluation is greater or equal to 5.0, the final grade of the subject will be pass 5.0

Regulations for carrying out activities

The conditions and regulations to carry out will the exams and assignments and will be announced in class and/or through Atenea (digital campus).

Bibliography

Basic:

Goebel, Dan M.; Katz, Ira. Fundamentals of electric propulsion: ion and hall thrusters. Hoboken: Wiley, 2008. ISBN 9780470429273.

Others resources:

Hyperlink

MITOpenCourseWare

MIT Open Courseware, Notes on Space Propulsion, by Manuel Martínez-Sánchez