Advanced Space Propulsion

Academic Year: (2021 / 2022) **Review date: 13-07-2021**

Department assigned to the subject: Bioengineering and Aeroespace Engineering Department

Coordinating teacher: AHEDO GALILEA, EDUARDO ANTONIO

Type: Compulsory ECTS Credits : 3.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Design of Space Systems

OBJECTIVES

The course is focused in Electric Space Propulsion, as the new leading technology for spacecraft propulsion both in Near-Earth and Deep-Space applications.

The goals of the course are to provide skills that allow students understanding of

- the benefits and limitations of electric rocket propulsion versus classical chemical rocket propulsion, for different missions scenarios
- the different electric propulsion devices and their main principles of operations
- basic notions of plasmas with application to the physics of electric thrusters
- performances and testing
- design and operational parameters and technological constraints

Additionally the course includes a lesson devoted to present briefly the operational principles, physics, performances and applications of ramjets and scramjets.

DESCRIPTION OF CONTENTS: PROGRAMME

1. FUNDAMENTALS OF ELECTRIC PROPULSION
Figures of merit for propulsion.
Specific thrust versus specific impulse.
Chemical versus electric propulsion(EP).
Optimal specific impulse.
Missions for EP: main types, historical milestones.
Plasma generation and acceleration mechanisms.
The EP family of thrusters

2. PLASMA PHYSICS APPLIED TO PROPULSION
Maxwell equations. On plasma typical units.
Quasineutrality. Debye sheaths and plasma-surface interaction.
The velocity distribution function and Boltzmann equation.
Multifluid formulations.
Main collisional processes (elastic, ionizing, Coulomb, CEX).
Magnetized particle dynamics.
Magnetized fluid dynamics: generalized Ohm and Fourier laws.

3. GRIDDED ION THRUSTERS
Principles of operation: discharge chamber, grids, hollow cathode.
The electric circuit.
Global model of discharge chamber:
plasma production,
current and power balances, magnetic confinement.
Inter-grid physics; the Child law.
Plasma plume expansion.
Performance laws.
Thermionic emission.
Hollow cathode physics.

Thruster lifetime

4. HALL EFFECT THRUSTERS
Principles of operation.
Experimental characterization.
The 2D multifluid formulation.
Anomalous diffusion.
Anode sheath.
Secondary electron emission at ceramic walls.
The simplified 1D model: formulation and solution.
Global performance analysis and thrust mechanisms.
Wall sputtering.
Thermal loads. Plasma and circuit oscillations.
Design of magnetic circuit.
Alternative configurations (TAL, cylindrical, two-stage, HEMP)

5. ADVANCED PLASMA THRUSTERS
Magnetoplasmadynamic thruster (with self and applied fields)
The helicon plasma thruster: RF production and magnetic nozzle acceleration.
Micropropulsion.

LEARNING ACTIVITIES AND METHODOLOGY

They combine
- lectures with audiovisual support
- discussion and solving of exercises and problems
- homework assignements
- quizzes

Tutorials can be both personally or through Aula Global

ASSESSMENT SYSTEM

In order to pass the subject in the ordinary call, two requirements need to be met:
1) to have a MINIMUM mark of 4.0 over 10 in the end-of-term exam;
2) to have a minimum overall mark of 5.0 over 10 (weighing 60% the end-of-term exam mark and 40% the mark of the continuous evaluation).

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	40

BASIC BIBLIOGRAPHY

- D. GOEBEL, I. KATZ FUNDAMENTALS OF ELECTRIC PROPULSION, WILEY, 2008
- R. JAHN PHYSICS OF ELECTRIC PROPULSION, DOVER, 2006