General information		
Academic subject	Physics of space electric propulsion	
Degree course	Laurea Magistrale in Physics – II year	
Academic Year	2022-2023	
European Credit Transfer and Accumulation System (ECTS)	3	
Language	English	
Academic calendar (starting and ending date)	II semester: 06/03/2023 – 26/05/2023	
Attendance	Recommended	

Professor/ Lecturer	
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Virtual headquarters (Microsoft Teams code)	
Tutoring (time and day)	Friday, 10:00-12:00 (on request)

Syllabus	
Learning Objectives	Specialized preparation in the electric propulsion concepts and systems, with particular emphasis on the mechanisms of ion production and acceleration
Course prerequisites	Thermodynamics, kinetic gas theory, electromagnetism, atomic and molecular physics, computational physics
Contents	1. History and fundamentals of space electric propulsion: rocket equation, power supply penalty, mission analysis. 2. Basics of plasma physics: 2.a Kinetic and fluid descriptions 2.b Individual character of plasma: Collisions in plasmas, Single-particle motion 2.c Collective character of plasma: Ideal plasma, Debye length and Langmuir frequency, Transport in plasma (diffusion and mobility), Plasma-wall transition and interaction, Plasma waves. 3. Electric propulsion: Electrothermal propulsion (resistojet and arcjet), Electrostatic propulsion (FEEP and Ion thruster), Hall thruster, Electromagnetic propulsion (pulsed plasma, MPD and magnetic nozzle thrusters) 4. Numerical models for plasma propulsion with laboratory experience (programming with python)
Books and bibliography	- R.G. Jahn, Physics of Electric Propulsion, Dover, 2006. - D.M. Goebels, I. Katz, Fundamentals of Electric Propulsion: Ion and Hall Thrusters, Wiley, 2008. - M. Andrenucci, Electric Propulsion: Concepts and Implementations, AP, 2022.
Additional materials	- Slides and lecture notes provided by teacher

Work schedule			
Total	Lectures	Hands on (Laboratory, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
Hours			
68	26	2	40
ECTS			
3			

Teaching strategy	
Lecture	Class lectures using blackboard and slide presentation
Numerical Laboratory	Programming with python numerical codes to describe plasma kinetics and dynamics in simple thruster configurations

Expected learning outcomes	

Knowledge and understanding on:	○ Plasma collective and individual particle behaviours ○ Kinetic description of plasma out-of-equilibrium ○ Electromagnetic field configuration for gas ionization and ion acceleration ○ Computational kinetic and fluid-dynamic approaches for plasma simulation
Applying knowledge and understanding on:	○ Gas discharges configurations ○ Space plasma propulsion for satellite station keeping and deep space missions
Soft skills	• **Making informed judgments and choices** ○ knowledge acquisition, critical understanding and capability of using in a creative and constructive way the information from the course lectures to develop analytical and numerical models of plasma thruster discharges up to propose original solutions • **Communicating knowledge and understanding** ○ ability to illustrate the reading matter thoughtfully, clearly, synthetically, effectively and with propriety of expression • **Capacities to continue learning** ○ ability to approach the specialistic literature and develop a critical spirit ○ ability to work in a group, and to be inserted quickly and effectively in the workplace

Assessment and feedback	
Methods of assessment	Interview where the student will typically be required to: - answer questions on one or more topics of the course; - develop in writing of the solution to an original problem addressable by using the information from the course lectures in a creative and constructive way. Both aspects will be weighted equally (50%).
Evaluation criteria	• **Knowledge and understanding** ○ illustrate the derivation from first principles of his/her solution to the given problem(s) by the introduction of the relevant simplifications and/or approximation; ○ justify the introduction of the simplifications and/or approximations used in the derivation; ○ assess and discuss the expected level of accuracy and limits of application of the proposed solution. • **Applying knowledge and understanding** ○ use the acquired knowledge to solve problems of plasma acceleration • **Autonomy of judgment** ○ Developing physical and mathematical tools to properly model physical problems relative to plasma discharges • **Communicating knowledge and understanding** ○ express in a proper way physical and mathematical concepts characterizing plasma space propulsion • **Communication skills** ○ Acquire an appropriate rigorous language to communicate plasma science • **Capacities to continue learning** ○ Develop mathematical and physical tool to model electric thrusters
Criteria for assessment and attribution of the final mark	Clarity in the oral exposition of the physical concepts
Additional information	