SPACE DYNAMICS AND MISSIONS - 2024/5

Module code: EEE3039

Module Overview

Expected prior learning: Students are expected to be familiar with the module contents of EEE1031, EEE1032, EEE2035 and equivalent. Students are also expected to be familiar with the basic principles of computer programming such as the writing of a function, for/while loops, if/else statements.

It is helpful, but not essential, to have studied module EEE2043 – Space Engineering and Mission Design or to have equivalent learning.

Student Journey: This module applies Engineering Mathematics concepts introduced in year 1 and 2 to the motion of objects in space. Combined with EEEM009 - Advanced Guidance Navigation & Control, which builds upon EEE3039 concepts to present students with a more in-depth overview of space-related hardware and software, EEE3039 aims at laying out the foundation for describing, predicting, and controlling the motion of objects in Space (both in terms of spacecraft position and orientation with respect to suitable reference frames).

Module purpose: This module gives a hands-on approach to mission analysis and develops mathematical descriptions of the natural orbital and rotational motions of spacecraft. Material is delivered through a series of lectures, group problem solving and assessed assignments. The application to mission design is explored through group work and coding assignments.

Module provider

Computer Science and Electronic Eng

Module Leader

BARESI Nicola (Maths & Phys)

Number of Credits: 15

ECTS Credits: 7.5

Framework: FHEQ Level 6

Module cap (Maximum number of students): N/A

Overall student workload

Independent Learning Hours: 89

Lecture Hours: 10

Tutorial Hours: 11

Laboratory Hours: 10

Guided Learning: 10

Captured Content: 20

Module Availability

Semester 1

Prerequisites / Co-requisites

None.

Module content

Kinematics & Kinetics:

Newton's laws of inertia; Inertial and Rotating Frames; Transport Theorem; Euler, Coriolis, and Centrifugal accelerations; Inertial VS Rotating Vectors.

Satellite Orbits:

Kepler’s laws and Newton’s derivation of Keplerian orbits. Energy and angular momentum related to orbital geometry. Time along orbit – Kepler’s problem, mean and eccentric anomalies.

Orbits in 3D, orbital elements. Orbital perturbations – sun synchronous and Molniya orbits. Critical inclination and frozen orbit.

Coordinate Systems and Time:

Equinoxes, solstices, first point of Aries, ECI frame. The obliquity of the ecliptic, Precession and nutation of Earth. Solar and sidereal time, fictitious Sun, universal time, GPS time and TAI. Julian date and MJD.

Mission Design:

Satellite groundtracks, repeat groundtrack orbits, Launch windows. Hohmann transfer and bi-elliptic transfers. Planetary flybys.

Attitude Coordinates:

Attitude matrix and properties; Euler’s theorem and eigenaxis description; vector decomposition; Euler angles and roll, pitch, yaw; Quaternions, quaternion product; Kinematic differential equations.

Dynamics of a Rigid Body:

Angular velocity, angular momentum, Moments of Inertia, principal axes, Euler’s equations, integrals of motion – rotational energy, total angular momentum. Motion of the angular momentum vector, torques. Polhode plots; Torque-free Motion for General and Axisymmetric Bodies; Gyroscopic Stiffness; Dual-Spin Spacecraft Configuration; Gravity Gradient

Modern Astrodynamics Topics:

The equations of the Circular Restricted Three-Body Problem; Jacobi integral and Zero-velocity curves. Introduction to equilibrium points and periodic orbits near Lagrangian points.

Assessment pattern

Assessment type	Unit of assessment	Weighting
Coursework	COURSEWORK	30
Examination	2HR INVIGILATED (OPEN BOOK) EXAM	70

Alternative Assessment

N/A

Assessment Strategy

The **assessment strategy** for this module is designed to provide students with the opportunity to demonstrate the learning outcomes. The written examination will assess the knowledge and assimilation of terminology and theory of orbital motion and spacecraft pointing. It will assess the ability to analyse problems by applying mathematical models to solve and predict disturbance effects and mitigation. The coding assignment will evaluate the students ability to program key astrodynamics concepts and put together a practical mission design solution.

Thus, the **summative assessment** for this module consists of the following.

· **Software assignment** An assignment involving the programming of and exploration of simple space flight mechanics concepts. (max. 20 pages) (assignment deadline should be checked in the Assignment Calendar)

· Open-book invigilated written examination

Formative assessment and feedback

For the module, students will receive formative assessment/feedback in the following ways.

· During lectures, by question and answer sessions

· One to one discussions with lecturer during problem solving sessions

· Peer feedback during group problem solving

· Through guided learning on SurreyLearn through provided material and problem solutions

· During supervised software laboratory sessions

· Via marking of coursework report

Module aims

- To introduce the student to develop a solid understanding of the classical dynamics of spacecraft and apply this knowledge in mission design for achieving pre-specified objectives and adequate pointing. This is to be achieved through a series of lectures, regular group problem solving with direct interaction with the lecturer and one software-based assignment.

Learning outcomes

Ref		Attributes Developed	
001	Design and propagate orbits using orbit elements and Cartesian coordinates	KCT	C2, C3
002	Select orbits most useful for space applications	CPT	C5, C7
003	Model and propagate the rotational dynamics of a rigid spacecraft via attitude coordinates	KC	C2, C6
004	Report in written format the outcome of individual advanced calculations associated with space flight mechanics	PT	C16, C17

Attributes Developed

C - Cognitive/analytical

K - Subject knowledge

T - Transferable skills

P - Professional/Practical skills

Methods of Teaching / Learning

The teaching strategy is through a taught theoretical foundation, interposed with direct group problem solving and with application of theory to real missions. A more significant mission design is worked on through software labs, where some aspects are looked at in greater depth. In all aspects there is direct interaction between lecturers and the groups to provide feedback on their understanding, and to push their understanding to solve new problems based on their knowledge.

Learning and teaching methods include the following.

Teaching and learning is by pre-recorded lectures, in-class discussion and problem solving sessions, and assessed software assignments.

Pre-recorded lectures plus problem solving and group discussion classes.

Assignment labs, plus a one-off software programming introduction

Indicated Lecture Hours (which may also include seminars, tutorials, workshops and other contact time) are approximate and may include in-class tests where one or more of these are an assessment on the module. In-class tests are scheduled/organised separately to taught content and will be published on to student personal timetables, where they apply to taken modules, as soon as they are finalised by central administration. This will usually be after the initial publication of the teaching timetable for the relevant semester.

Reading list

https://readinglists.surrey.ac.uk
Upon accessing the reading list, please search for the module using the module code: **EEE3039**

Other information

The following of the Five Pillars of the Surrey Curriculum framework are embedded by this module:

- **Sustainability** – introduces students to the space debris problem and the space environment
- **Global and Cultural Intelligence** – showcases how orbital design enables cutting-edge Earth Observation and Surveillance applications. Discusses examples of successful spacecraft missions, which were only possible through international cooperation and multi-disciplinary approaches.
- **Digital Capabilities** are expanded via hands-on MATLAB coding assignments that expose students to software-enabled analyses and applications.
- **Employability** – teaches core principles of space flight mechanics that underpin any space-related engineering job. Besides, Astrodynamics per se is a viable employability route, ranking 7th across the 20th Engineering related disciplines listed on the 2020 'Skills demand for early career space jobs' report.
- **Resourcefulness and Resilience** – MATLAB coursework allows students to hone their problem-solving skills in a peer-supervised lab environment. Students are also thought about the importance of working in teams to deliver spacecraft missions via real-life examples and spacecraft missions.

Programmes this module appears in

Programme	Semester	Classification	Qualifying conditions
Aerospace Engineering BEng (Hons)	1	Optional	A weighted aggregate mark of 40% is required to pass the module
Aerospace Engineering MEng	1	Optional	A weighted aggregate mark of 40% is required to pass the module
Electronic Engineering with Space Systems BEng (Hons)	1	Compulsory	A weighted aggregate mark of 40% is required to pass the module
Electronic Engineering with Space Systems MEng	1	Compulsory	A weighted aggregate mark of 40% is required to pass the module
Space Engineering MSc	1	Compulsory	A weighted aggregate mark of 40% is required to pass the module