University of Toronto

Spacecraft Dynamics and Control

AER506H1F

Course Information and Syllabus

Fall 2018

This course begins with the foundations required to describe the motion of point masses, systems of masses, and rigid bodies. After a brief look at launch vehicle dynamics, the course then focuses on the orbital motion of spacecraft resulting from gravitational forces, controlling this motion using manoeuvres, and the effects of external disturbances. Lastly, the rotational motion of rigid bodies and its stability are studied, and various passive and active attitude control strategies are considered.

Pre-requisites: AER301 (Dynamics) and AER372 (Control Systems) *or* equivalent
Recommended for: AER1503 (Spacecraft Dynamics and Control II)

It is hoped that, by the end of this course, the students will be able to:

- Physically and mathematically describe a rigid body‘s attitude and its rotational and translational dynamics, as expressed in arbitrary reference frames.
- Classify the constants of orbital motion and associate each type of orbit and its properties with its corresponding conic section.
- Evaluate the classical orbital elements using spacecraft's position and velocity information and vice versa, employing the constants of motion.
- Identify the major external sources that affect spacecraft's orbits, and employ mathematical tools to estimate the magnitude of such perturbations.
- Predict how various manoeuvres influence spacecraft's orbits, and design a realizable interplanetary mission, while estimating the amount of resources required.
- Define stability of translational and rotational motion, and make use of these definitions to assess the stability of Lagrange points and spinning spacecraft.
- List various methods of attitude stabilization and mathematically describe the rotational motion of spacecraft resulting from each method, while accounting for internal energy dissipation.
- Apply knowledge of control systems to design active attitude controllers, assess their performance, and compare and contrast linear and nonlinear control.

Administration

Course Instructor	Behrad Vatankhahghadim Behrad.Vatankhahghadim@mail.UToronto.ca *Office*: UTIAS Room 193, (416)667-7722 *Office Hours and Work Sessions*: Location TBA, Thursdays 11:30 - 12:30 *or* by appointment
Teaching Assistant	Teaching Assistant Qingrui.Zhang@mail.UToronto.ca

Textbooks

Required	*Spacecraft Dynamics and Control: an Introduction* A. H. J. de Ruiter, C. J. Damaren, J. R. Forbes; Wiley, 2013.
Recommended	*Spacecraft Attitude Dynamics* P. C. Hughes; Wiley, 1986 *or* Dover, 2004.

Both items are available at the U of T Bookstore and the U of T Libraries.

Assessment

Assignments	Problem Set 1, due on: September 27th	4%
	Problem Set 2, due on: October 11th	4%
	Problem Set 3, due on: November 1st, December 5th	6%
	Problem Set 4, due on: November 22rd	4%
	Problem Set 5, due on: December 5th	4%
Midterm Test	Type B, GB120, October 25th	28%
Final Exam	Type X, location and date to be determined	50%

Coursework Submission Policy

All problem set solutions shall be submitted in person to the instructor, with some parts uploaded to the course website on Quercus, if thus requested by a particular assignment. All problem sets will be released at least two weeks prior to the above due dates. Problem Set 3 will be submitted in two stages to ensure balanced distribution of work over several weeks and to allow for intermediate feedback.
No late submission of any of the assignments will be accepted, unless to accommodate documented medical or family emergencies.

Lecture Schedule

The following list provides a tentative schedule of the topics to be discussed. Both the subjects and the weeks in which they will be delivered are tentative, and may be modified to match the flow of the discussion. Week 1 (W1) corresponds to the September 6th class, Week 2 (W2) to the September 11th and 13th classes, and so forth until Week 14 (W14) to the December 4th class.

W1	*Introduction*, Fundamentals	**W8**	*Review*, *Midterm*
W2	Fundamentals, Kinematics	**W9**	Stability, Torque-Free Motion
W3	Dynamics, Orbital Mechanics	**W10**	Spin and Dual-Spin Stabilization
W4	Orbital Mechanics and Description	**W11**	Energy Dissipation, Disturbances
W5	Perturbations, Launch Dynamics	**W12**	Gravity-Gradient, Active Control
W6	Manoeuvres, Interplanetary Travel	**W13**	Bias-Momentum, Nonlinearity
W7	Three-Body Problem, *Reserve*	**W14**	*Review*, *Conclusion*

Supplementary lecture notes will be posted in advance on QUERCUS. Tutorial sessions may follow immediately after some of the above lectures. The tutorial questions to be discussed will also be available in advance on QUERCUS. The students are strongly encouraged to attempt them on their own, before the corresponding tutorials take place.

Academic Integrity

The University of Toronto treats cheating and plagiarism very seriously. All suspected cases of academic dishonesty will be investigated as outlined in the Code of Behaviour on Academic Matters (www.governingcouncil.utoronto.ca/policies/behaveac.htm). If any of the students has questions or concerns about what constitutes appropriate academic behaviour or appropriate research and citation methods, he/she is expected to seek out additional information on academic integrity from the instructor or from other institutional resources (see http://academicintegrity.utoronto.ca/).