San José State University
Aerospace Engineering Department
AE168: Aerospace Vehicle Dynamics & Control
Fall 2016

Course and Contact Information

Instructor: Prof. J.M. Hunter

Office Location: Engineering 272F

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Office Hours: MW 10:30am – 1:15pm; M 4:30 – 6:00pm

Class Days/Time: MW 3:00 – 4:15pm

Classroom: Engineering 164

Prerequisite: Grade of C− or better in AE140, AE157, AE165 and Math129A

Course Format

Class Website: https://sjsu.instructure.com Under the courses tab, select this course.

For issues related to Canvas, please contact the eCampus Help Desk. The Help Desk can give technical support for issues encountered in Canvas Courses. Phone: (408) 924-2337
Submit a help ticket using the following URL: https://isupport.sjsu.edu/ecampus/ContentPages/Incident.aspx.
While logged into Canvas, click on the word **Help** on the upper right corner of the screen.

Online Class: Usually this class will meet in person in Engineering 164. Sometimes, however, the class will meet online, using a WebEx link. In these cases, I will announce the online schedule ahead of time and post the link on Canvas.

Course Description

Aircraft/spacecraft dynamics, stability and control. Linearization and Euler transformations. Eigenvalues and eigenvectors. State space and transfer function analysis of dynamics of aerospace vehicles. Feedback control design and synthesis using advanced control techniques.

Course Goals

1. *To review aircraft static stability and develop the concepts of aircraft dynamic stability.*
2. *To learn the principles of automatic feedback control.*
3. *To gain an understanding of aircraft motion and develop the means to control that motion.*
4. *To derive spacecraft equations of motion.*
5. *To design passive and active control of spacecraft.*

Course Learning Outcomes

1. *Review the principles of static longitudinal aircraft stability.*
2. *Represent vehicle orientation using Euler angle rotations.*
3. *Develop perturbation equations for aerospace vehicle six degree-of-freedom motion.*
4. *Estimate lateral and longitudinal stability derivatives from aircraft geometry.*
5. *Understand why deflecting the ailerons produces a yawing moment.*
6. *Determine the natural frequencies and damping ratios of the short period and phugoid modes.*
7. *Evaluate the effect of compressibility on aircraft handling qualities.*
8. *Understand the significance of the Cooper-Harper rating scale.*
9. *Evaluate the effect of altitude on aircraft handling qualities.*
10. *Derive transfer functions and plot vehicle time response.*
11. *Use root locus and frequency response techniques to design closed-loop control systems: rate-damping, attitude control, altitude control.*
12. *Derive the equations of a satellite using gravity-gradient passive control.*
13. *Design a satellite control law using a momentum wheel.*
14. *Design a control law for a spacecraft which is 3-axis controlled by cold-gas jets.*

Required Texts

Hunter: Aerospace Vehicle Dynamics & Control Course Reader (Maple Press)

Roskam: Airplane Flight Dynamics and Automatic Flight Controls, Parts I & II
https://shop.darcorp.com/index.php?route=product/category&path=60

References

Etkin: Dynamics of Atmospheric Flight
Blakelock: Automatic Control of Aircraft and Missiles
McGruer: Aircraft Dynamics and Automatic Control
Perkins & Hage: Airplane Performance and Stability & Control
Nise: Control Systems Engineering
Agrawal: Design of Geosynchronous Spacecraft
Ogata: Modern Control Engineering

Course Requirements and Assignments

Homework	15%
Project	25%
Two Hour Exams	40%
Final Exam	20%

Reading assignments will be posted for most classes and should be completed before coming to class. Homework problems will be assigned every week or two. These homework sets are essential to your understanding. Allow 8 – 10 hours per week for homework. Often we will work problems in groups during the class period, sometimes for credit, sometimes not. As homework is graded and returned to you, I will post the solutions on Canvas and work selected problems on the board. If there is a particular problem that you would like to see worked out, please let me know and I will be sure to make time to do this.

Final Examination

A comprehensive written final exam will be given on Monday, December 19, 12:15 – 2:30pm, in Engineering 164.

Grading Information

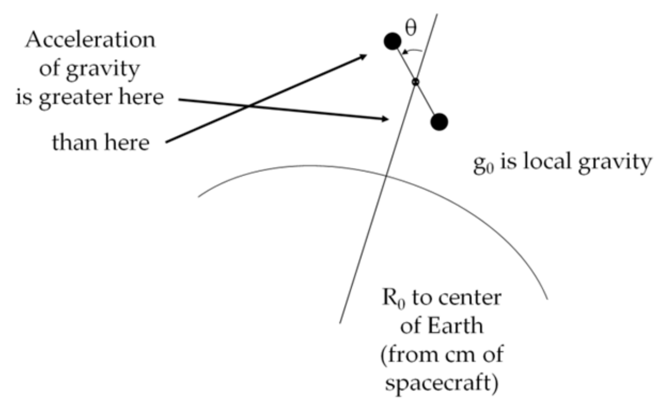
Problem grades are based on:

i conceptual understanding (i.e., identifying the correct physical principle or law of motion),
ii setting up the problem equations, and
iii solving the problem for a numerical or symbolic expression.

Two old exam problems are shown below, with partial credit indicated.

(25 pt) A spacecraft is passively stabilized using gravity gradient torque. The equation of motion is:

$$\ddot{\theta} + \frac{3g_0}{R_0}\theta = \frac{M_y}{I_y}$$



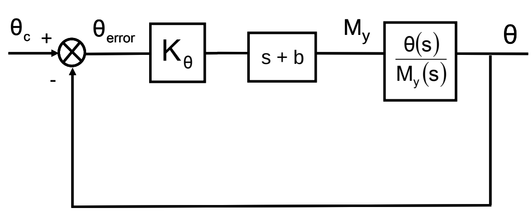
M_y = torque about the spacecraft y axis
R_0 = distance from Earth's center to spacecraft
g_0 = acceleration of gravity at R_0

For 200 mile LEO orbit: $\frac{3g_0}{R_0} = \frac{4x10^{-6}}{\sec^2}$

a) Find the open-loop transfer function: $\frac{\theta(s)}{M_y(s)}$

b) Plot the open-loop poles and roughly sketch the open-loop impulse response.

c) An engineer designs a *lead compensation* (s + b) for the system so that the feedback control system is as shown below. Let b = 0.001, put the closed-loop poles at s = - .002 ± 0.002j and find K_θ.



d) Draw the root locus. The break-in point is s = -0.00325

e) Sketch the closed-loop time response for the closed-loop poles in part c.

Partial Credit

(4 pt) Open-loop transfer function
(4 pt) Sketch of open-loop impulse response
(4 pt) Actual Characteristic Equation (ACE)
(4 pt) Desired Characteristic Equation (DCE)
(3 pt) Equating ACE and DCE and solving for K_θ
(6 pt) Root locus & closed-loop impulse response

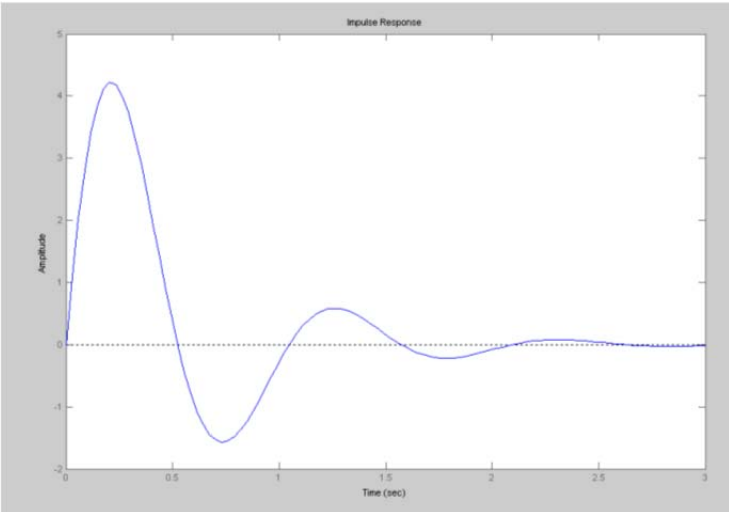
(20 pt) The motion of a wind tunnel model aircraft can be approximated as:

$$\ddot{\alpha} - \left(M_q + M_{\dot{\alpha}}\right)\dot{\alpha} - M_\alpha \alpha = M_{\delta e}\delta e$$

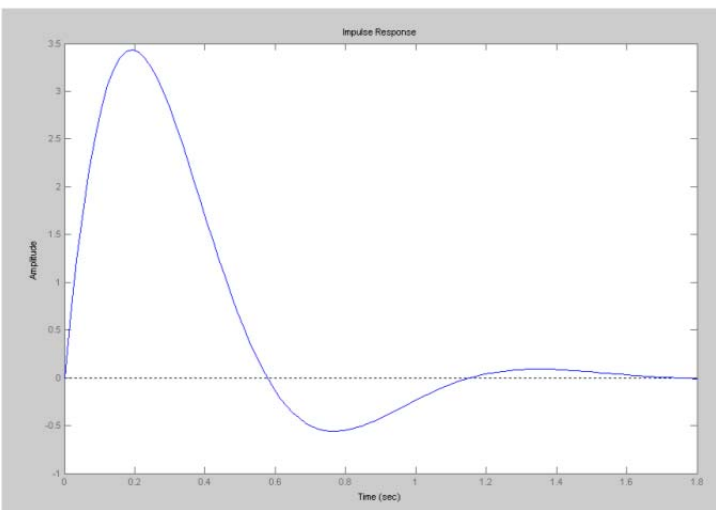
Plot A is the impulse response of the aircraft in its initial configuration.
Plot B is the impulse response of the aircraft after $\left(M_q + M_{\dot{\alpha}}\right)$ has been increased.

If M_α and $M_{\delta e}$ do not change from Plot A to Plot B, how much does $\left(M_q + M_{\dot{\alpha}}\right)$ increase between the two plots?

Plot A:



Plot B:



Partial Credit

(12 pt) Calculation of damped natural frequency, damping ratio and undamped natural frequency from each plot
(4 pt) Finding open-loop transfer function
(4 pt) Equating coefficients and solving for change in $M_q + M_{\dot{\alpha}}$

Determination of Grades

Grading Scale: 100 – 97% A+; 96.9 – 93% A; 92.9 – 90% A-; 89.9 – 87% B+;
86.9 – 83% B; 82.9 – 80% B-; 79.9 – 77% C+; 76.9 – 73% C; 72.9 – 70% C-; 69.9 – 67% D+;
66.9 – 63% D; 62.9 – 60% D-; < 59.9% F. All exams must be taken to receive a passing grade.

Homework & project assignments are due at the beginning of the class period. Late assignments will not be accepted without extenuating circumstances and previous permission from the instructor.

University Policies

Dropping and Adding Students are responsible for understanding the policies and procedures about add/drop, grade forgiveness, etc. Refer to the current semester's Catalog Policies section at http://info.sjsu.edu/static/catalog/policies.html. Add/drop deadlines can be found on the current academic calendar web page located at http://www.sjsu.edu/academic_programs/calendars/academic_calendar/. The Late Drop Policy is available at http://www.sjsu.edu/aars/policies/latedrops/policy/. Students should be aware of the current deadlines and penalties for dropping classes. Information about the latest changes and news is available at the Advising Hub at http://www.sjsu.edu/advising/.

Academic Integrity Your commitment as a student to learning is evidenced by your enrollment at San Jose State University. The University's Academic Integrity policy, located at http://www.sjsu.edu/senate/S07-2.htm, requires you to be honest in all your academic course work. Faculty members are required to report all infractions to the office of Student Conduct and Ethical Development. The Student Conduct and Ethical Development website is available at http://www.sa.sjsu.edu/judicial_affairs/index.html.

Instances of academic dishonesty will not be tolerated. Cheating on exams or plagiarism (presenting the work of another as your own, or the use of another person's ideas without giving proper credit) will result in a *failing grade for the course* and sanctions by the University. For this class, all assignments are to be completed by the individual student unless otherwise specified. If you would like to include your assignment or any material you have submitted, or plan to submit for another class, please note that SJSU's Academic Policy S07-2 requires approval of instructors.

Campus Policy in Compliance with the American Disabilities Act If you need course adaptations or accommodations because of a disability, or if you need to make special arrangements in case the building must be evacuated, please make an appointment with me as soon as possible, or see me during office hours. Presidential Directive 97-03 requires that students with disabilities requesting accommodations must register with the Disability Resource Center (DRC) at http://www.drc.sjsu.edu/ to establish a record of their disability.

Time Required Success in this course is based on the expectation that students will spend, for each unit of credit, a minimum of forty-five hours over the length of the course (normally 3 hours per unit per week with 1 of the hours used for lecture) for instruction or preparation/ studying or course related activities including but not limited to internships, labs, clinical practica. Other course structures will have equivalent workload expectations as described in the syllabus.

Course Schedule

Week	Lecture Outline
1	Airplane Static Longitudinal Stability
2	Airplane Static Lateral / Directional Stability
3	Rigid body equations of motion & linearization
4	Perturbation equations: longitudinal & lateral / directional
5	Longitudinal stability derivatives
6	Lateral / directional stability derivatives
7	Dimensional perturbation equations
8	Longitudinal dynamic stability
9	Closed loop control
10	Attitude-hold & altitude-hold autopilot design
11	Lateral / directional control
12	Launch vehicle control
13	Gravity gradient dynamics & passive control
14	Spacecraft attitude dynamics & 3-axis control
15	Thruster control
16	Final Exam Review