AE430 - Stability and Control of Aerospace Vehicles

INSTRUCTOR: **Pier Marzocca**
OFFICE: **234 CAMP, MAE Dept**
CLASS SCHEDULE: **176 CAMP MW 10:00-11:15**
OFFICE HOURS: **MW 1:30 - 3:30, CAMP 234 or by appointment**
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Prerequisites

AE 455/ME 455, MA 231 (Calculus III), MA 232 (Differential Equations) or equivalent

Brief Course Outline

An introduction to atmosphere flight vehicle dynamics. Static stability and control. Equations of motion. Dynamic stability and control. Classical control theory. Transfer functions and block diagrams. Routh's criterion, Root locus techniques, Bode plots. Modern control theory. State space techniques. Observability, and controllability. Flying qualities, ratings and regulations. Application to aircraft autopilot design

Textbook

Nelson, R. C., *Flight Stability and Automatic Control*, 2nd Ed., McGraw-Hill Co., 1998

References

Etkin, B., and Reid, L. D., *Dynamics of Flight: Stability and Control*, 3rd Ed., John Wiley & Sons, 1996
Pamadi, B. N., *Performance, Stability, Dynamics, and Control of Airplanes*, AIAA Education Series, 1998

Learning Objectives

- Introduce students to the fundamental concepts of atmospheric flight dynamics
- Enable students to analytically estimate static and dynamic stability derivatives
- Enable students to study the stability of longitudinal and lateral motions using the linearized equations
- Enable students to obtain responses to actuation of open-loop and closed-loop controls
- Enhance the students' written, oral, and graphical communication skills

Course Goals

- Overview principles of flight and the classical/modern theory of stability and control
- Present conventional and unified notation for flight mechanics variables, forces, and moments
- Derive classical, uncoupled rigid body equations of motion used for S&C analysis of aircraft
- Define and physically explain the static and dynamic stability and control derivatives
- Understand the concepts of equilibrium, neutral point, trim, etc.
- Introduce transfer function representation, dynamic stability, and modes of motion
- Present examples of flight models used in analysis and design

Grades

All tests will be closed book, closed notes, and held during the class period (1 hr 15 min).
[1] Homework 15%
[2] Test 1 20% (~ Sep 25)
[3] Test 2 20% (~ Oct 28)
[4] Test 3 20% (~ Nov 25)
[5] Project 25% (~ Project report and oral presentation - Dec 10)

Project

Select one of the two projects illustrated next:

1) To enhance learning, the students are required to evaluate the stability and control characteristics of actual airplanes. Each team (of two students) selects an airplane, obtains its geometric and mass data, computes stability and control derivatives, and studies the longitudinal and lateral-directional motions. Students submit work-in-progress reports at mid-semester and final reports at the end and make oral presentations.

2) To enhance learning, the students are required to find one or more literature article (from a journal, book, etc.) where the problem of stability and control of airplanes has been treated. Each team (of two students) should choose any of the topics under the general category of stability and control of airplane. However, aside from this constraint, the primary driving force in the selection of the paper topic should be your interest. You should review the literature in order to become familiar with your topic and the issues surrounding it. Students submit work-in-progress reports at mid-semester and final reports at the end and make oral presentations.

Note: Start this assignment early! ALL topics must be approved by the instructor, due date: end of September.

Detailed Outline

Flight Mechanics **(Chapter 1)**

- Atmospheric flight mechanics, aerodynamic nomenclature, reference frames

Static Stability and Control **(Chapter 2)**

- Longitudinal static stability
- Pitch control
- Lateral / directional static stability
- Roll & yaw control
- Stick forces

Aircraft Equations of Motion **(Chapter 3)**

- Linearized equations of motion
- Dynamic stability

Longitudinal Motion **(Chapter 4)**

- Pure pitching motion
- Longitudinal EOM
- Phugoid and short-period modes
- Longitudinal flying qualities

Lateral Motion **(Chapter 5)**

- Pure rolling motion
- Pure yawing motion
- Lateral EOM
- Spiral, roll, and Dutch roll approximations
- Lateral flying qualities
- Aeroelastic effects

Introduction to Modern Control Theory **(Chapter 9)**

- State-space modeling, Solution of state equations
- Controllability and observability
- State feedback design

Aircraft Autopilot Design Using Modern Control Theory **(Chapter 10)**

- Longitudinal stability augmentation
- Lateral stability augmentation

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Course Rules

Reading Assignments

The student should read ahead one or two sections before each class. Topics will be presented in the syllabus order. This will greatly facilitate understanding the lectures and will save time in the long run.

Problem Assignments

The instructor-assigned problems are not necessarily those suggested on the book. Late problems will generally not be accepted (except for reasons of illness, etc). The first few minutes of the due date class will be devoted to the problems due that day.

Homework papers should be orderly and logical, with a straightedge/circle template used for all diagrams. Use 8-1/2"x11" paper (no legal sizes or pages tom from composition books), pencils (no pens), and staples in the upper left-hand comer. Submit your paper unfolded, with name, course, and due date in the upper right-hand comer. Use of only the front sides of the pages is recommended, but if you have strong ecological feelings to the contrary, use the backs as well.

If **computer-oriented problems** will be assigned, the submission of only a computer program listing and output is unacceptable. Begin as with any mechanics problem: With pencil and paper, apply the fundamental principles to the problem at hand. Bring the development to a critical point at which the computer is utilized to manipulate numbers, produce a plot, etc. Cite any program used; if you write the program, attach it to your solution as an appendix. As with any engineering problem, delay the introduction of numbers as long as possible.

The **three tests** will cover all material up to and including the last lecture before the test, but will stress the material since the last test. All tests will be closed book, closed notes, and held during the class period (1 hr 15 min). Each test and the exam may include short-answer questions and will include at least one problem similar to homework assignments. Make-up tests only for reasons of illness, etc. For the **final project** see the guideline of the course.

Honor Policies

The tests and the exam are closed book, closed notes, no personal aid tests. One 8.5x11-inch piece of paper with whatever you wish written on both sides is allowed for each test and the exam. Electronic calculators are allowed, but arithmetic will count very little toward your grade, whereas the demonstration of understanding the basic concepts will be weighed heavily. The pledge to be written out and signed on tests is as follows: "I pledge that I have neither given nor received aid on this test."

You may consult other students in your section if you have difficulties with the homework problems - in fact, discussion is encouraged. However, direct copying of the homework problems from solutions of any kind will be deemed an honor violation.

Grade Weighting

Homework:15%; 3 Tests: 60%; Project: 25%;

Letter Grade Standards: A (90-100), B (80-89.9), C (70-79.9), D (60-69.9), F (0-59.9)

The interpretation here is that a numerical grade of 90 or better is guaranteed to be an A, 80 or better a B, etc. It may be, for example, that an 89 is judged to be an A- in a particular class, but the pattern cannot emerge until after the examination. So there can be no discussion of letter grades until the end of all the work of the semester; until then, use the above scale as your guideline.

Classroom Policies

Although attendance is not considered in determining the final grade, you are highly encouraged to attend every class. Doing so will make life easier and help ensure that you obtain the best return for your educational expenditures. You should be in the classroom promptly on the hour, ready to begin work. In consideration of your fellow students, please do not talk in class. But feel free to ask any question at any time. A good question can really enliven a class!!

All parties MUST arrive for class on time. Seats near the door will be reserved for students who have a previous class more than ten minutes away. The goal here is to have NO distractions during class.

General Comments

- Although many of you do not realize this now, being a student is probably the best job you will ever have. I would like to challenge you to take pride in your status. Realize that there is much satisfaction in working hard to be superior student. Recognize, too, that being a good student is actually easier than being a poor student - certainly it is much more pleasant! With these thoughts in mind, let me wish you the best in all your courses.