

# Syllabus: ASEN 3728 Aircraft Dynamics

Professor Zachary Sunberg

Spring 2024

## Meetings

T/TH 8:30-9:45, AERO 120 – Lecture video will automatically be posted online - see Piazza for link.

## Course Staff

### Instructor

Professor Zachary Sunberg

AERO 263 [zachary.sunberg@colorado.edu](mailto:zachary.sunberg@colorado.edu) (please make a public or private Piazza post before emailing)

**Office Hours:** Posted on Piazza

### Teaching Assistants

**Office Hours:** Posted on Piazza

- Scott Mckinley [scott.mckinley@colorado.edu](mailto:scott.mckinley@colorado.edu)
- Ben Kraske [benjamin.kraske@colorado.edu](mailto:benjamin.kraske@colorado.edu)
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## Textbook

Bernard Etkin and Lloyd Reid, *Dynamics of Flight: Stability and Control, 3rd Edition*. 1996, John Wiley and Sons.

## Prerequisites

ASEN 2002, 2003, 2004, and APPM 2360 (min grade C-).

## Overview

This course covers the key ideas that enable: (i) an understanding of how aircraft work and tools for quantitative analysis, and (ii) design methods to achieve specified dynamical behavior. Because aircraft exist in many different forms, and new designs continue to be developed, the focus is on the common principles that underlie atmospheric flight, so that a solid basis can be formed for future work in any direction. Concrete treatment of these ideas, tools, and methods is provided through working problems consisting of analysis, simulation, and design, including development of simulation models for two very different vehicles: a quad-copter and a conventional airplane.

In their full expression, aircraft dynamics possess astounding complexity. It is a tribute to the ideas developed by aviation's pioneers that a relatively simple understanding can often be obtained, leading to

clear insights and design principles. While these concepts are not inherently difficult, they do lie outside most common experience, and they depend on new nomenclature and strange notation that can seem overwhelming at first. It is only through diligent and careful use of this new language that the underlying simplicity can be grasped and conveyed on exams; mastery of the language of aircraft dynamics is perhaps the most important predictor for success in the course.

The course has been designed to develop a conceptual grasp of the key ideas below, and to demonstrate proficiency in using these concepts to solve problems, construct and validate simulations, and to explain behaviors and results obtained. In particular, engineering reasoning skills using these concepts are stressed in assignment solutions and examinations. The key learning objectives are:

- Vector mechanics
  - Vector representation in coordinate frames
  - Change of coordinate frame representation (coordinate rotation)
  - Relative motion, frame derivatives
  - Change of derivative frame: velocity rule
- How aircraft dynamics models are created and what the terms mean
  - 3D rigid body translational model
    - \* Kinematics
    - \* Dynamics, external forces
    - \* Effects of wind
  - 3D rigid body rotational model
    - \* Kinematics, Euler angle attitude representation
    - \* Dynamics, Euler moment equations, external moments
  - External forces and moments
    - \* Aerodynamic effects
    - \* Control effects
    - \* Steady flight conditions, trim states
- How aircraft dynamics models are simulated
  - State space models
  - Numerical integration
- How dynamical behavior is understood and specified
  - Linearization
  - Decoupling
  - Stability derivatives
  - Modal solutions
  - Stability characterizations
  - Modal specifications
- How feedback control is designed to meet behavioral objectives
  - Sensor/feedback selection, control structure and gain selection
  - Effects on mode eigenvalues

## Course Components

Material and concepts are introduced, and student mastery is evaluated using several mechanisms throughout the course:

**Reading** – The textbook provides the essential basis for the course, including the concepts, terminology, notation, methods, and examples used to convey the course topics. Specific reading assignments will be given covering key sections of the book; some book sections are not covered in the course. Some supplementary material will also be provided. The textbook contains a wealth of information, but the concepts and notation are new to most; some sections need to be read more than once to fully grasp the material.

**Lectures** – These are intended to emphasize key ideas and methods that make the material easier to grasp. They are therefore a counterpart to the reading, not a replacement. The value of lectures is dependent on your participation in them. Passive “watching” will provide little benefit. Active note taking is critical to developing first-hand familiarity with the notation, terminology, and methods, and to gaining comfort

in using them. Although lectures will be recorded, this is a poor substitute for your own lecture notes. Questions are encouraged during lectures and will be prompted often.

**Homework** – Homework problems provide individual practice in solving problems of varying difficulty and sometimes will also involve computing. Collaboration on homework is allowed, but the work you submit must be your own. Students are encouraged to use homework as a means to ensure their individual mastery of the subject.

**In-Class and Reading Quizzes** – These will cover the reading material, and lectures. They will consist of true-false and multiple-choice-style questions similar in format to questions that will be on the exams.

**Exams** – These are the primary means of evaluation of your individual grasp of the course material. Exams will include both conceptual questions and quantitative problems. Precise use of terminology and notation is stressed. The final exam is comprehensive in that it will contain material from the entire course, but emphasis will be placed on the final portion of the course material. **There will be a statute of limitations on when exam grades can be corrected. Any corrections on exam scores must be made before the next exam, or two weeks after the exam was returned, whichever comes later.** The only corrections made after this time period will be for simple addition errors in scoring.

## Websites

- **Piazza** will host course discussions, announcements, and host solutions that are not posted publicly. Students should ask questions here rather than emailing the course staff unless there is an important reason. The class signup link is at \_\_\_
- **Gradescope** will be used for assignments.
- **Github** will be used to host all course materials. You can download all materials without using git, but learning the basics may be much more convenient, not to mention useful for your future career.
- **Canvas** will be used minimally as a landing page and anything that cannot be accommodated by the above websites.

## Attendance and Participation

Learning is a collaborative effort between the instructor and students. Students are expected to attend all lectures, ask questions, and participate in discussions. The course staff will encourage attendance through in-class quizzes. **If a student needs to miss class occasionally, please do NOT notify the course staff.** Several of the lowest in-class quiz scores will be dropped to accommodate absences (see grading breakdown below).

## Grading Philosophy

Grades are assigned according to an absolute standard designed to indicate your level of competence in the course material. The final grade indicates your readiness to continue to the next level in the curriculum. The AES faculty have set these standards based on our education, experience, interactions with industry, government laboratories, others in academy, and according to the criteria established by the ABET accreditation board.

The course grade is primarily dependent on individual measures of competency, i.e., exams. The other course assignments are designed to enrich the learning experience and to enhance individual performance, not to substitute for sub-standard individual competency. This policy makes it important to use the assignments to enhance your learning.

Grades for the course are earned set based on the following criteria:

- A, A- Demonstrates mastery of the course material in both conceptual and quantitative aspects.
- B+, B Demonstrates comprehensive understanding of the material, with a solid conceptual grasp of key concepts and strong quantitative work.
- B-, C+ Demonstrates good understanding of most key concepts, with few major quantitative errors.

- C Demonstrates satisfying understanding of the material with sufficient quantitative work.
- C- Demonstrates adequate understanding of the material to proceed to the next level; sufficient quantitative work.
- D Very little understanding is evident, consistently poor quantitative work.
- F Unsatisfactory performance.

Graders will assess whether responses provided by students reflect knowledge, understanding and reasoning processes that meaningfully contribute to answering questions posed on assignments. Empty and “fluff” responses, e.g., repeating questions, listing buzzwords, irrelevant diagram drawing, etc., will not suffice. This subject is difficult and non-intuitive, and since this is the first time most (if not all) students have seen this material, it is naturally assumed that all students must work hard and put in effort to learn the concepts. Therefore, hard work is necessary, but not sufficient by itself, to do well. Your effort must translate to demonstrable individual understanding for success.

## Grade Breakdown

- **5% In-class Quizzes.** (lowest 4 dropped)
- **5% Reading Quizzes.** (lowest 2 dropped)
- **16% Homework.** (lowest dropped)
- **44% Two Midterm Exams (22% each).**
- **30% Final Exam.**

## Late Policy

To ensure proper progression through the course, students are expected to begin assignments early and submit homework assignments on time. However, in order to provide for minor unforeseen events or responsibilities, students may turn in late homework assignments within 72 hours of the due date with a 10% penalty. No homework will be accepted after 72 hours beyond the due date.

## Additional Policies

### Classroom Behavior

Students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote, or online. Failure to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, or political philosophy.

For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

### Requirements for Infectious Disease

Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all applicable campus policies and public health guidelines to reduce the risk of spreading infectious diseases. If public health conditions require, the university may also invoke related requirements for student conduct and disability accommodation that will apply to this class.

If you feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the guidance of the Centers for Disease Control and Prevention (CDC) for isolation and testing. If you have been in close contact with someone who has COVID-19 but do not have any symptoms and have not tested positive for COVID-19, you do not need to stay home but should follow the guidance of the CDC for masking and testing.

## **Accommodation for Disabilities, Temporary Medical Conditions, and Medical Isolation**

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or [dsinfo@colorado.edu](mailto:dsinfo@colorado.edu) for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Students are expected to start on assignments early so that minor temporary medical conditions do not prevent them from turning assignments in on time. In addition, the late policy is designed to accommodate minor temporary medical conditions. If you have a major medical emergency that prevents you from completing an assignment, please contact the instructor as soon as possible to discuss accommodations.

## **Preferred Student Names and Pronouns**

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

## **Honor Code**

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include but are not limited to: plagiarism (including use of paper writing services or technology [such as essay bots]), cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty.

All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution: [honor@colorado.edu](mailto:honor@colorado.edu), 303-492-5550. Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Visit Honor Code for more information on the academic integrity policy.

## **Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation**

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits protected-class discrimination and harassment, sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these concerns, and individuals who have been subjected to misconduct can contact OIEC at 303-492-2127 or email [cureport@colorado.edu](mailto:cureport@colorado.edu). Information about university policies, reporting options, and support resources can be found on the OIEC website.

Please know that faculty and graduate instructors must inform OIEC when they are made aware of incidents related to these policies regardless of when or where something occurred. This is to ensure that individuals impacted receive outreach from OIEC about resolution options and support resources. To learn more about reporting and support for a variety of concerns, visit the [Don't Ignore It](#) page.

## **Religious Accommodations**

Campus policy requires faculty to provide reasonable accommodations for students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please communicate the need for a religious accommodation in a timely manner, i.e. at least a week before the event.

See the campus policy regarding religious observances for full details.

## **Mental Health and Wellness**

The University of Colorado Boulder is committed to the well-being of all students. If you are struggling with personal stressors, mental health or substance use concerns that are impacting academic or daily life, please contact Counseling and Psychiatric Services (CAPS) located in C4C or call (303) 492-2277, 24/7.

Free and unlimited telehealth is also available through Academic Live Care. The Academic Live Care site also provides information about additional wellness services on campus that are available to students.