ASEN 3728 AIRCRAFT DYNAMICS
FALL 2023
SYLLABUS

LECTURE

Tuesday & Thursday 1:00 - 2:15 pm AERO 120

INSTRUCTORS

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Office Hours: Wednesday 1-2 pm

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TEXTBOOK

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

Supplemental: *Small Unmanned Aircraft: Theory and Practice, Randal W. Beard and Timothy W. McLain, Princeton University Press, 2012.*

Supplemental: *Flight Stability and Automatic Control, 2nd Ed., Robert C. Nelson, McGraw-Hill, 1998.*

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 individually and in assigned groups, consisting of analysis, simulation, and design problems, 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
    - 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
    - Effects on mode eigenvalues

TEACHING MODALITIES

Lecture – Lectures will be in person throughout the semester. All lectures will be automatically recorded and uploaded to the course Canvas page via CU's Classroom Capture system.

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 (copying is not); however, students are encouraged to use homework as a means to ensure their individual mastery of the subject. In-class group problem-solving will allow for considerable collaborative learning opportunities.

Reading Quizzes – These will cover the reading material, and lectures. Quiz grades will contribute to your individual course grade and are designed to encourage you to come to class and lab prepared. 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. In-class, written exams are planned for Week 7 and Week 11; the final exam is TBD by the university. 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.

LOGISTICS

1. **Office hours –** office hours for TFs will be held nominally during the "Study Hall" times – Tue./Thu. 5:30-7:00 PM - in AERO N100. This is intended to provide ease-of-access to TF help on the weekly assignments, but any questions about course material are welcome. This mode of "supervised learning" can be quite efficient, particularly if students are prepared by attempting the assignments ahead of time and come to the "Study Hall" sessions with questions. Additional office hours with instructors and TFs will also be scheduled. Private meetings with instructors or TA/TFs can also be arranged if needed.

2. **Email & Piazza questions** – Students are encouraged to post and discuss questions on Piazza (accessed via Canvas). Instructors actively monitor the discussions on Piazza and post answers or comments if necessary. Students may only email the instructor(s) questions not related to homework. DO NOT expect an immediate response. Any question received by 5 PM should typically receive a response within 24 hours. Questions received after 5 PM may not receive a response until noon two days after. Always include "ASEN 3728" in the subject of any emails related to the class (enables efficient search).

3. **Attendance** – Attendance at all lectures is essential. Students who come to class prepared and participate in discussions typically have a more rewarding experience.

4. **Taking your own notes** – Firsthand contact with the notation and diagrams is key to understanding the material in this course, and to conveying your understanding on exams. Lectures will be recorded for repeated viewing, to ensure details are not missed. But there is no substitute for taking your own notes.

5. **Homework** – Collaboration is permitted on homework. This means you may discuss the means and methods for solving problems and even compare answers, but you are not free to copy solutions from classmates or from Internet resources. The work that you turn in must be your own--copying is not allowed for any assignments. Students who are caught copying homework solutions will be reported for violation of honor code and may incur both academic and non-academic sanctions. Homework is submitted individually through Canvas/Gradescope. Please indicate clearly where each problem begins and ends. (You do not need to use a separate sheet for each problem.) Written work must be neat and readable with adequate spacing and margins. *Final answers must be indicated with a box*. Very messy work will be returned to you without being graded and a score of zero recorded. Two of the lowest homework scores will be dropped and not count toward the final grade.

6. **Reading Quizzes** – Reading quizzes will be given weekly in an on-line format through Canvas. These will cover the reading material and lectures. Quiz grades will contribute to your course grade. Reading quizzes will be regularly administered through Canvas every week, except when there is an exam. Students will have at least 48 hours to complete each quiz from the time of release. Two of the lowest quiz scores will be dropped and not count toward the final grade.

7. **Examinations & Comprehensive Final** – Exams will be given during the class periods. The final exam is scheduled according to University policy. Any type of collaboration or copying on an exam, or final constitutes cheating and will result in an F for the course. An honor code violation or accusation report will be filed. 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. Students will be expected to complete both portions during the scheduled course time.

8. **Deadlines –** Deadlines must be enforced to ensure fairness and to enable timely grading. Late assignments are subject to a 50% penalty per day (e.g., 0-24 hours late = 1 day penalty) except under extenuating circumstances. If such a circumstance occurs you are expected to contact the instructor and TFs immediately by email, before the due date. No other accommodations will be provided, e.g., a hectic schedule or crashed computer will not be considered. Please plan for these contingencies by including some margin in your schedule. If you know in advance you will not be able to submit your homework on

the day it is due, you may submit your assignment on Gradescope any time prior to the due date. It is your responsibility to manage assignment submissions and deadlines.

GRADING

Grading Philosophy

Assignments and exams are graded to an absolute standard designed to indicate your level of competency 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 academe, and according to the criteria established by the ABET accreditation board. As with all other standards that you will encounter throughout your professional, these standards are non-negotiable.

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.

In this course, students will be graded on a positive/"value added" system – that is, 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, verbal/buzzword spaghetti throwing, random diagram drawing, etc., are easily seen through and 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

Your final grade breakdown is as follows.

Description	Percentage
Reading Quizzes	5%
Homework	15%
Mid-term Exams (2 Exams)	50% (25% Each)
Final Exam	30%
Total Score	100%

Note: two of the lowest quiz scores and homework scores will be dropped and will not count towards the final grade.

EXAM SCHEDULE

The first two exam dates are subject to possible revision to later dates (if needed) during the semester:

Exam 1:	Tuesday Oct. 10	1:00 – 2:15 pm
Exam 2:	Tuesday Nov. 7	1:00 – 2:15 pm
Final Exam:	TBD by university	

HOMEWORK SCHEDULE

Homework Assignments will be posted and due on weekly basis. See the end of this document for the full schedule. Homework must be completed individually. The lowest two homework scores will be dropped and not count towards the final grade.

READING QUIZ SCHEDULE

Reading quizzes will be conducted on-line through Canvas. They will be open each week (except when there is an exam) for at least 48 hours from the initial posting time. Often but not always, two attempts are provided for each quiz with the highest score recorded. Reading quiz submissions will not be accepted after the deadline. The lowest two quiz scores will be dropped and not count towards the final grade.

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 DISEASES

Members of the CU Boulder community and visitors to campus must follow university, department, and building health and safety requirements and all public health orders to reduce the risk of spreading infectious diseases.

The CU Boulder campus is currently mask optional. However, if masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class. Students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct & Conflict Resolution. Students who require accommodation because a disability prevents them from fulfilling safety measures related to infectious disease will be asked to follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

For those who feel ill and think you might have COVID-19 or if you have tested positive for COVID-19, please stay home and follow the further guidance of the Public Health Office. For those who 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.

ACCOMMODATION FOR DISABILITIES, TEMPORARY MEDICAL CONDITIONS, AND MEDICAL ISOLATION

Disability Services determines accommodations based on documented disabilities in the academic environment. If you qualify for accommodations because of a disability, submit your accommodation letter from Disability Services to your faculty member in a timely manner so your needs can be addressed. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance.

If you have a temporary medical condition or required medical isolation for which you require accommodation, contact the faculty instructor immediately. For assignment or exam accommodations, notify the faculty at least three weeks prior to the due date or exam date. Also see Temporary Medical Conditions on the Disability Services website.

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 for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

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, 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 believe they have been

subjected to misconduct can contact OIEC at 303-492-2127 or email 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 have a responsibility to 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 an outreach from OIEC about their options for addressing a concern and the support resources available. To learn more about reporting and support resources for a variety of issues, visit Don't Ignore It.

RELIGIOUS HOLIDAYS

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, inform the instructors of such conflicts at least three weeks in advance.

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.

Schedule

The expected course schedule is as follows (some updates and adjustments may occur during course of the semester):

	Lectures			Assignments	
Dates		**Tuesday**	**Thursday**	**Monday**	**Friday**
08/29-08/31	Equations of Motion; Intro to Aircraft Dynamics and Control: Quadrotor Example	Introduction; Nomenclature	Coordinate Frames and Euler Angles (Ch 4.1, 4.4, App. A.4)	-	-
09/05-09/07		Equations of Motion – Kinematics (Ch. 4.1, 4.4)	Equations of Motion – Dynamics (Ch. 4.2-4.3,4.5,4.7)	Quiz 1 due	HW 1 due
09/12-09/14		Quadcopter Dynamics	Linearization	Quiz 2 due	HW 2 due
09/19-09/21		Quadcopter Modal Solutions	Quadcopter Stability and Control	Quiz 3 due	HW 3 due
09/26-09/28		Quadcopter Guidance	Longitudinal Forces/Moments (Ch2.1-2.3)	Quiz 4 due	HW 4 due
10/03-10/05		Longitudinal Trim and Stability (Ch. 2.1-2.4)	Longitudinal Stability Derivatives (Ch 5.1-5.5)	Quiz 5 due	HW 5 due
10/10-1/12	Fixed-Wing Aircraft: Longitudinal Stability and Control	**Exam 1**	Longitudinal Linear Model (Ch. 4.9-4.10)	-	HW 6 due
09/17-10/19		Longitudinal Modes (Ch. 6.2)	Short Period Approximation (Ch. 6.3)	Quiz 6 due	HW 7 due
10/24-10/26		Longitudinal Control (Ch. 7.1-7.7)	Lateral Forces and Moments	Quiz 7 due	HW 8 due
10/31-11/02		Lateral Stability Derivatives; Yaw Stiffness (Ch. 3.8-3.9; Ch. 4.11)	Dihedral Effect (Ch. 3.11-3.12)	Quiz 8 due	HW 9 due
11/07-11/09	Fixed-Wing Aircraft: Lateral Stability and Control	**Exam 2**	Lateral Damping Derivatives	-	HW 10 due
11/14-11/16		Lateral Cross Coupling and Side Forces (Ch. 5.6-5.8)	Lateral Linear Model (Ch.4.7-4.10)	Quiz 9 due	HW 11 due
11/21-11/23	FALL BREAK				
11/28-11/30		Lateral Dynamic Modes (Ch. 6.7)	Lateral Modal Approximations	Quiz 10 due	HW 12 due
12/05-12/07		Lateral Control Derivatives; State and Stability Augmentation (Ch. 6.8)	Aircraft Handling Qualities and Control Design Criteria	Quiz 11 due	HW 13 due
12/12-12/14	Fixed-Wing Aircraft: Stability and Control of Complete Aircraft	Aircraft Transfer Function Matrices	Review: students come with questions; no slides	Quiz 12 due	HW 14 due
12/16-12/20	Final Exam: Date/Time TBD				