THE OHIO STATE UNIVERSITY
Mechanical and Aerospace Engineering

AAE 3520: Flight Vehicle Dynamics
Autumn 2017

Course Handout

NOTE: Modifications to this syllabus may be required during the semester. Any changes to the syllabus will be announced in class.

Catalog Course Description: Introduction to mathematical modeling of dynamics (equations of motion) for rigid bodies with specific application towards aircraft and spacecraft. Credits: 3

Pre-requisites: AAE 2201, AAE 2201, ME 2030 or ME 430, and AEROENG-BS standing. Also, working knowledge of at-least one programming language is required, e.g. MATLAB©.

Course Objectives: By the end of this course, you should be able to do the following:

- Write equations of translational motion of aircraft and spacecraft, i.e. their motion as a dimensionless particle of finite mass,
- Write nonlinear equations for six degree of freedom motion of aircraft,
- Analyze dynamic aircraft flight conditions using the nonlinear equations of motion,
- Use small perturbation theory to identify flight modes and understand static and dynamic stability,
- Identify appropriate attitude parameterization for rigid bodies,
- Analyze free and forced rotational dynamics of rigid bodies, with application to aircraft and spacecraft

Contribution of course to meeting the professional component (ABET): The table below describes the contribution of this course to development of specific components of professional growth as described in the ABET program criteria. The components have been divided into three streams: aeronautical (ae), astronautical (as) and mechanical (me): There is high coverage for professional components

Aeronautical		Astronautical		Mechanical	
(ae1) Aerodynamics:	×	**(as1)** Orbital mechanics:	×	**(me1)** Apply principles of engineering, basic science & mathematics (inc. multivar. calculus & differential eqns) to model, analyze, design & realize physical systems, components or processes:	✓
(ae2) Aerospace materials:	×	**(as2)** Space environment:	×		
(ae3) Structures:	×	**(as3)** Attitude determination and control:	✓		
(ae4) Propulsion:	×	**(as4)** Telecommunications:	×		
(ae5) Flight mechanics:	✓	**(as5)** Space structures:	×	**(me2)** Work professionally in both thermal and mechanical systems areas:	×
(ae6) Stability and control:	✓	**(as6)** Rocket propulsion:	×		
Engineering Design: 20% **Mathematics**: 40 %, **Engineering Sciences**: 40 %					

(**ae5**) and (**ae6**). In addition to the program criteria described above, this course will also contribute to the development of proficiency in the subject of numerical methods and the use of computational tools to solve engineering problems.

Relationship of course to program outcomes (ABET): This course will meet several program outcomes as described in the ABET criteria, described in the table below. There will be high coverage for outcomes (**a**), (**c**), (**e**) and (**k**) in this course. These outcomes will be assessed throughout the semester

Program outcome	Met?	Program outcome	Met?
(a) an ability to apply knowledge of mathematics, science, and engineering	✓	**(b)** an ability to design and conduct experiments, as well as to analyze and interpret data	×
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	✓	**(d)** an ability to function on multidisciplinary teams	×
(e) an ability to identify, formulate, and solve engineering problems	✓	**(f)** an understanding of professional and ethical responsibility	×
(g) an ability to communicate effectively	×	**(h)** the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	×
(i) a recognition of the need for, and an ability to engage in life-long learning	✓	**(j)** a knowledge of contemporary issues	×
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	✓		

via homework assignments (to be completed by individual effort) and selected problems on exams. In addition, there is low coverage for outcome (**i**), which will be assessed through homework.

Instructor: Mrinal Kumar (kumar.672@osu.edu). Office Location: E530 Scott Labs, Telephone: (614) 688-2884. Office hours: M, W 3-4 PM. Also welcome to come in any other time if I am available.

Teaching Assistants: Awaiting assignment.

Class meeting times: M-W-F, 1:50 - 2:45 PM

Meeting location: Scott Labs E004

Textbook/Software: There is no official textbook for this course. Material will be gathered from a number of sources and class notes will be provided. The following books are notable references for the topics considered in this course and can be used as supplemental reading material.

1. *Introduction to Aircraft Flight Mechanics: Performance, Static Stability, Dynamic Stability, and Classical Feedback Control,* by Thomas R. Yechout, Publisher: AIAA Education Series, First Edition (May 2003), ISBN: 978-1563475771.
2. *Flight Dynamics*, by Robert F. Stengel, Publisher: Princeton University Press (September 27, 2004); ISBN: 978-0691114071. Also check out lecture notes on Prof. Stengel's website: http://www.princeton.edu/~stengel/MAE331Lectures.html
3. *Mechanics of Flight*, by Warren Phillips, Publisher: Wiley, Second Edition (Dec. 2009), ISBN: 978-0-470-53975-0.
4. *Analytical Mechanics of Space Systems,* by Hanspeter Schaub and John L. Junkins, AIAA Education Series; 2^{nd} edition (September 30, 2009), ISBN: 978-1600867217. [Note: This is a unique textbook because it contains an excellent treatment of particle mechanics, rigid body dynamics, Hamiltonian dynamics as well as orbital mechanics, all in the same textbook.]
5. *Modern Flight Dynamics*, by David K. Schmidt, Publisher: McGraw Hill, First Edition, (2012), ISBN: 978-0-07-339811-2.

Note: You *are not* required to buy any of the above books. They have been suggested as alternative reading material if you wish to further explore the subject.

Attendance/Other expectations: Students are expected to attend all lectures although there are no penalties for missing classes. Any activity that acts as a distraction for other students (e.g. talking on phone/texting/Rubik's cube/juggling etc.) is not permitted while class is in progress.

Course outline: The table below provides a tentative weekly schedule for this course. Please note that the table is meant only as a guideline *and there may be significant variations depending on several factors*, e.g. how easily the introductory material is grasped by the class, allowing me to proceed to more advanced topics.

Material	Week #	HW Due?	Comments
Introduction, particle mechanics: coordinate systems, rotation matrices, transport theorem	1	×	
	2	✓	
Newtonian mechanics: application to translational motion of air- and spacecraft	3	✓	Labor day week
	4	✓	
Attitude representations, rigid body kinematics.	5	✓	
	6	×	Exam 1 (F)
Eulerian Mechanics: dynamics of rigid configurations. Similarity transformation to principal axes	7	×	
	8	✓(on W)	Autumn break
Aircraft 6DOF nonlinear EOM, analysis	9	✓	
Small perturbation theory (linearization), static stability, force/moment derivatives	10	✓	
	11	×	Exam 2 (F)
Dynamic stability, flight modes	12	✓	
	13	✓	
	14	×	Thanksgiving week
Spacecraft attitude dynamics	15	✓	
	16	×	Exam 3 (W)

Grading policy: All HW assignments are to be completed individually. You are encouraged to discuss assigned problems with fellow students, but you must turn in your own work. Shared computer programs will not be considered for evaluation. Details of grade distribution:

- **Homework Assignments**: 25%
- **In-class exams** (3): 75%.
  - **Sep 29 (Friday), 2017. 1:50 - 2:40 PM.**
  - **Nov 03 (Friday), 2017. 1:50 - 2:40 PM.**
  - **Dec 13 (Wednesday), 2017. 2:00 - 3:45 PM.**

Late assignment policy: You are allowed to turn in 1 assignment late without penalty (your 1st late submission). The 2nd late submission will incur a penalty of 25% and 50% the 3rd onwards.

All exams will be closed notes, closed book. Required formulas will be provided to you.

Make-up exam policy: Due to large size of the class, there will be no early/late exams. Please make your travel arrangements according to the exam dates specified in the syllabus.

Grading scale:

Score	Grade	Score	Grade	Score	Grade	Score	Grade	Score	Grade
> 92	A	> 86	B+	> 76	C+	> 66	D+	< 59	E
> 89	A-	> 82	B	> 72	C	> 62	D		
		> 79	B-	> 69	C-	> 59	D-		

The above table represents a guideline for letter-grade allocation. In borderline cases, I reserve the right to assign a grade different from the grade derived from the table above. Such an assignment will be based on the progressive performance of the student in the course. For example, a student ending up with a final score of 85 may be awarded an A- (instead of B+) if her performance has progressively improved over the course of the semester.

Academic Misconduct: It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct at http://studentconduct.osu.edu

Accommodation for Students with Disabilities: Students with disabilities that have been certified by the Office for Disability Services will be appropriately accommodated and should inform the instructor as soon as possible of their needs. The Office for Disability Services is located in 098 Baker Hall, 113 W. 12th Avenue; Phone: 292-3307, TDD 292-0901, VRS 429-1334; http://www.ods.ohio-state.edu/

Grievances and Solving Problems: According to University Policies, if you have a problem with this class, you should seek to resolve the grievance concerning a grade or academic practice by speaking first with the instructor or professor. Then, if necessary, take your case to the department chairperson, college dean or associate dean, and to the provost, in that order. Specific procedures are outlined in Faculty Rule 3335-7-23. Grievances against graduate, research, and teaching assistants should be submitted first to the supervising instructor, then to the chairperson of the assistant's department.

Counseling Services: As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The Ohio State University offers services to assist you with addressing these and other concerns you may be experiencing. If you or someone you know are suffering from any of the aforementioned conditions, you can learn more about the broad range of confidential mental health services available on campus via the Office of Student Life Counseling and Consultation Services (CCS) by visiting ccs.osu.edu or calling (614) 292- 5766. CCS is located on the 4th Floor of the Younkin Success Center and 10th Floor of Lincoln Tower. You can reach an on-call counselor when CCS is closed at (614) 292-5766 and 24 hour emergency help is also available through the 24/7 National Prevention Hotline at 1-(800)-273-TALK or at suicidepreventionlifeline.org

Diversity: The Ohio State University affirms the importance and value of diversity in the student body. Our programs and curricula reflect our multicultural society and global economy and seek to provide opportunities for students to learn more about persons who are different from them. We are committed to maintaining a community that recognizes and values the inherent worth and dignity of every person; fosters sensitivity, understanding, and mutual respect among each member of our community; and encourages each individual to strive to reach his or her own potential. Discrimination against any individual based upon protected status, which is defined as age, color, disability, gender identity or expression, national origin, race, religion, sex, sexual orientation, or veteran status, is prohibited.

Copyright: The materials used in connection with this course may be subject to copyright protection and are only for the use of students officially enrolled in the course for the educational purposes associated with the course. Copyright law must be considered before copying, retaining, or disseminating materials outside of the course.

Prepared by: Mrinal Kumar August 01, 2017