

MAE 466 – Spacecraft Dynamics – Fall 2021

Department of Mechanical and Aerospace Engineering
West Virginia University

INSTRUCTOR: Dr. Andrew Rhodes, Teaching Assistant Professor
Office: ESB 829
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CLASS: Schedule: M/W/F 10:00-10:50
Location: ESB 801
Credit: 3 hours

PREREQUISITE: MAE 476 Space Flight and Systems
Grade: D- or better

DESCRIPTION: Development of rigid-body equations of motion for aerospace vehicles. Introduction to spacecraft attitude representations, including direction cosine matrices, Euler angles, and quaternions. Brief discussion of airplane flight dynamics. Discussion of attitude dynamics, stabilization, and control in the presence of external torques. Brief discussion of attitude hardware.

TEXTBOOK: Instructor Notes and Handouts.

TECHNOLOGY: Webcam, digital/phone scanner, and internet access required.
MATLAB 2019 or newer
(<https://its.statler.wvu.edu/policies-and-procedures/matlab-software>)

OFFICE HOURS: Office hours are conducted virtually via email, video or voice calls, or forum discussions.
Instructor: M/W 11:00-12:30
If the instructor is not available at these times, then substitute times will be allotted in the same week.

GRADING:

Homework:	30%
Quiz:	10%
Project:	10%
Exam 1:	15%
Exam 2:	15%
Final Exam:	15%
<i>Floating Exam Credit:</i>	5%

The 10-Point Grading Scale is used to assign the final grade in this course.

TENTATIVE COURSE SCHEDULE

Week	Dates	Lecture Topic	Notes & Assignments
1	8/18	Intro. To Spacecraft Dynamics	
	8/20	Vector Mathematics.	
2	8/23	Coordinate Systems. Reference Frames.	
	8/25	Vector Kinematics.	
	8/27	Transport Theorem.	
3	8/30	Planar Particle Kinematics Example.	HW 1 Due
	9/1	3D Particle Kinematics Example.	
	9/3	Single Particle Dynamics.	Quiz 1
4	9/6	Labor Day (No Class)	
	9/8	Intro. Attitude Representations.	HW 2 Due
	9/10	Direction Cosine Matrix (DCM).	
5	9/13	DCM Kinematics, Addition & Subtraction.	
	9/15	Euler Angles.	
	9/17	Euler Angles to DCM	HW 3 Due
6	9/20	Euler Angles Kinematics.	Quiz 2
	9/22	Euler Angles Addition & Subtraction. Review.	
	9/24	Exam 1	
7	9/27	Axis-Angle.	
	9/29	Axis-Angle Kinematics, Addition & Subtraction.	
	10/1	Quaternion.	
8	10/4	Quaternion Kinematics.	
	10/6	Attitude Kinematics Review.	HW 4 Due
	10/8	Fall Break (No Class)	Midterm Grades Due 10/7
9	10/11	Wahba's Problem.	Assign Project
	10/13	Wahba's Problem Solutions.	
	10/15	Continuous System Dynamics.	HW 5 Due
10	10/18	Rigid Body Dynamics. Inertia Matrix.	
	10/20	Euler's Rotational Equation of Motion.	
	10/22	Rigid Body Dynamics Example.	Quiz 3, Project Task 1 Due
11	10/25	Rigid Body Dynamics Example.	Project Task 2 Due
	10/27	External Torques	Project Task 3 Due
	10/29	Torque Free Spin Stabilization.	HW 6 Due
12	11/1	Polhode Curves.	Quiz 4
	11/3	Nutation, Precession, & Body Spin.	Project Task 4 Due
	11/5	Exam 2	Project Task 5 Due

Week	Dates	Lecture Topic	Notes & Assignments
13	11/8	Torque Free Motion of Axisymmetric Spacecraft.	Project Task 6 Due
	11/10	Dual-Spin Spacecraft.	Project Task 7 Due
	11/12	Dual-Spin Equilibria and Stability.	HW 7 Due, Project Task 8 Due
14	11/15	Variable Speed Control Moment Gyro (VSCMG).	Project Task 9 Due
	11/17	Spacecraft with Single VSCMG.	Project Task 10 Due
	11/19	VSCMG Motor Torque Equations.	Quiz 5, Project Task 11 Due
15	11/22-11/26	Fall Recess (No Class)	
16	11/29	Gravity Gradient Stabilization.	
	12/1	Gravity Gradient Equilibria and Stability.	Project Task 12 Due
	12/3	Star Trackers and Star Catalogs.	HW 8 Due
17	12/6	Aerospace Sensors and Hardware.	Project Survey Due
	12/8	Aircraft Flight Dynamics.	Last Class
	12/10	Prep Day (No Class)	
18	12/13-12/17	Final Exam Week	

COURSE & STUDENT OUTCOMES

This is a key course for ABET Student Outcomes 1, 2 and 4. Definitions and descriptions are available at MAE Program Accreditation and Assessment

(<https://mae.statler.wvu.edu/home/aerospace-engineering-program-accreditation-and-assessment>)

Course Learning Outcomes	Student Outcomes
Implement several attitude representations and conversions in software.	1
Derive and apply the rigid-body equations of motion for spacecraft.	1
Analyze spacecraft attitude dynamics under various torque and torque-free scenarios.	2B
Calculate and compare the singularities of various attitude representation.	2B
Discuss historic and contemporary spaceflight missions and their impact on society.	4C

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

WVU POLICIES AND STATEMENTS

More information about WVU policies and more is available online at Academic Integrity Policy (<https://provost.wvu.edu/governance/academic-standards-resources/academic-integrity-policy>), Campus Student Code (<https://studentconduct.wvu.edu/campus-student-code>), and Syllabus Policies and Statements (<https://tlcommons.wvu.edu/syllabus-policies-and-statements>). Students are responsible for reviewing and understanding all policies. Listed below are specific policies that I wish to emphasize.

NOTICE OF COURSE RECORDING POLICY

Meetings of a course at West Virginia University (WVU), whether online or in-person, may be recorded. Recordings are not guaranteed, and are intended to supplement the planned class session. Recordings will be made available to class participants, which may include students, assistants, guest lecturers, and co-facilitators. Recordings may be shared by the instructor or institution in accordance with WVU Rules and policies. The Recordings are owned by and contain intellectual property of WVU. The Recordings may not be shared, copied, reproduced, redistributed, transferred, or disseminated in any form or by any means without the prior written consent of authorized officials of WVU.

INCLUSIVITY STATEMENT

The West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion. If you are a person with a disability and anticipate needing any type of accommodation in order to participate in your classes, please advise your instructors and make appropriate arrangements with the Office of Accessibility Services. (<https://accessibilityservices.wvu.edu/>) More information is available at the Division of Diversity, Equity, and Inclusion (<https://diversity.wvu.edu/>) as well.

SALE OF COURSE MATERIAL STATEMENT

All course materials, including lectures, class notes, quizzes, exams, handouts, presentations, and other course materials provided to students for their courses are protected intellectual property. As such, the unauthorized purchase or sale of these materials may result in disciplinary sanctions under the Student Conduct Code (<https://studentconduct.wvu.edu/campus-student-code>).

COVID-19 SYLLABUS STATEMENT

WVU is committed to maintaining a safe learning environment for all students, faculty, and staff. Should campus operations change because of health concerns related to the COVID-19 pandemic or other campus-wide emergency, it is possible that this course will move to a fully online delivery format. If that occurs, students will be advised of technical and/or equipment requirements, including remote proctoring software.

In a face-to-face environment, our commitment to safety requires students, staff, and instructors to observe the social distancing and personal protective equipment (PPE) guidelines set by the University at all times. While in class, students will sit in assigned seats when required and will wear PPE according to current University guidelines. Students who fail to comply may be referred to the Office of Student Conduct for sanctions.

COVID related absences fall under the University attendance policy found here:

<http://catalog.wvu.edu/undergraduate/enrollmentandregistration/#Attendance>. As detailed in the policy, a student who becomes sick or is required to quarantine during the semester should notify the instructor. The student should then work with the instructor to develop a plan to complete the course learning outcomes while he or she is absent.

ACADEMIC INTEGRITY STATEMENT

The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, instructors will enforce rigorous standards of academic integrity in all aspects and assignments of their courses. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the WVU Academic Standards Policy (<http://catalog.wvu.edu/undergraduate/coursecreditstermsclassification/>). Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see your instructor before the assignment is due to discuss the matter. In addition, The Statler Policy of Academic Integrity will be used to address instances of academic dishonesty according to the following table:

STATLER POLICY OF ACADEMIC INTEGRITY

(Approved by the Statler College Academic Standards Committee, 28 March 2019)

Case	Violation	Penalty
1	Cheating or plagiarism on minor course element (e.g. quiz, weekly lab report, homework as specified in the syllabus).	Report of academic dishonesty. Grade of zero on the entire minor course element. Possible one-letter reduction in final grade.
2	Cheating or plagiarism on a major course element (e.g. exam, project).	Report of academic dishonesty. Grade of zero on the entire major course element. Possible additional one-letter reduction in final grade. Possible UF † recommendation. Possible exclusion from further participation in class.
3	Collusion on major course element.	Report of academic dishonesty. Exclusion from further participation in class. Failure of the course. Recommendation for UF †.
4	Other (document alteration, tampering with records, etc.).	Report of academic dishonesty. Grade of zero on the entire major course element. Possible additional one-letter reduction in final grade. Possible failure in the course. Possible exclusion from further participation in the class. Possible UF † recommendation.

* Dismissal from the Statler College is permanent for Academic Integrity violations. Student conduct violations can be considered dismissal.

† UF– Unforgivable F Grade, cannot be replace under D-F repeat policy.

π Separable sanctions (e.g. dismissal from Statler College, suspension, or expulsion from WVU) will be recommended for aggravated or second Academic Integrity offenses.

§ Warning letters may be issued from the Statler College or the WVU Office of Student Conduct.

Sanctions will be assessed at the instructor and at the college/university levels. Additional sanctions may be assigned at the level of the instructor, college, and/or university.

Statler Policy on Smart Devices: The use of programmable calculators or smart devices (including smart-phones, smart watches, tablets, cameras, wearable devices, etc.) is prohibited unless specifically indicated by the instructor.