## Syllabus for ME 596 — Spacecraft Attitude Dynamics and Control

## Fall 2018 2H

**Instructor**: Dr. Chris Hall **Email:** Use Course Messages

**Office Location:** MECH 430 **Office Phone:** (505) 277-0210

**Office Hours:** By Appointment **Course Credits:** 3 hours

**Department of Mechanical Engineering Contact Information:**

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|---|---|---|
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**Lectures and Course Materials Online:** http://www.learn.unm.edu

**Technical Requirements**

- A high speed Internet connection is highly recommended, and is required for the three Exams.
- Supported browsers include: Chrome, Edge, Firefox, Internet Explorer, and Safari.
- Chrome is specifically required for using Proctorio when taking Exams.
- Detailed Supported Browsers and Operating Systems: https://help.blackboard.com/Learn/Student/Getting_Started/Browser_Support
- Check your browser configuration at: https://help.blackboard.com/Learn/Student/Getting_Started/Browser_Support/Browser_Checker

  Any computer capable of running a recently updated web browser shouldbe sufficient to access your online course. However, bear in mind that processor speed, amount of RAM and Internet connection speed can greatly affect performance.
- Online courses perform best on a high-speed Internet connection. Those using dial-up connections will experience longer page load times and much slower performance when accessing their online course. Many locations offer free high-speed Internet access including UNM's Computer Pods or one of UNM's many Statewide Centers

- **For UNM Learn Technical Support: (505) 277-5757 (M-F 8am - 5pm) or learn@unm.edu.**

**Text:** *Spacecraft Attitude Dynamics and Control*, C.D. Hall

Lecture Notes posted on learn.unm.edu

**Overview:** Space missions and how pointing requirements affect attitude control systems. Rotational kinematics and attitude determination algorithms. Modeling and analysis of the attitude dynamics of space vehicles. Rigid body dynamics, effects of energy dissipation. Gravity gradient, spin, and dual spin stabilization. Rotational maneuvers. Environmental torques. Impacts of attitude stabilization techniques on mission performance. Prerequisite: Dynamics (ME 306). Recommended corequisite: Control Systems (ME 380).

**Goal:** Students know how to formulate and solve the problems associated with analyzing, predicting, and controlling the attitude dynamics of spacecraft.

**Objectives:** Students can identify attitude control concepts.
Students can apply rotational kinematics to the pointing motion of spacecraft.
Students can apply attitude determination methods.
Students can apply rigid body mechanics to the pointing motion of spacecraft.

**Discussions:** Each module includes one or more discussion topics. The purpose of Discussions here is two-fold: 1) Discussions provide opportunities for student-to-student interaction that might otherwise not happen in an online course; 2) Engineers must regularly engage with co-workers, supervisors, customers, and others through discussions, which may be face-to-face or electronic interactions, and our Discussion assignments should be approached from this perspective.

Participation in discussion is graded and counts for 10% of your course grade. For most discussions, your initial post must be submitted by Wednesday at 11:59 PM (1 point), and you will not see other students' submissions until you have submitted your thread. For most discussions, you must make a substantive response to the submissions of three other students (3 points), and these responses are due by Friday at 11:59 PM. Late submissions will receive 0 points.

Your initial post must address the discussion assignment and must be grammatically correct. This post does not need to be a lengthy essay, but a one-sentence response will not receive credit. Similarly, your substantive responses must address the other students' initial posts. These responses do not need to be lengthy essays, but one-sentence responses will not receive credit. A sample initial post and a sample substantive response are provided in the material for the first week.

Each week, by 11:59 PM Friday, I will upload either a brief video or a text discussion of my observations of your discussions for that week.

**Homework Policy:** There are homework assignments each week, and each assignment specifies the due date (11:59 PM Monday of the following week, unless otherwise specified). Homework must be uploaded as a single pdf file by the due date. Late homework will not normally be accepted and will receive a grade of 0. In the event of family or work emergency, please contact me before the due date to make an arrangement for late submission. Each homework assignment will require some Matlab programming.

Each homework submission must be presented neatly, using complete sentences, and explanations for each step in the solution. You do not have to typeset your homework, but you should consider it to be a technical report. An example Homework "report" is presented with the material for the first week.

I will post a detailed solution to each homework assignment after the due date. Usually, I will have the homework assignment graded within 72 hours. If for some reason I am unable to meet that commitment, I will let you know by way of an announcement.

**MATLAB Assignments:** Several MATLAB programming assignments will be included in the homework assignments. MATLAB is available to all UNM students at http://it.unm.edu/download/

**Quizzes:** There are quizzes between the lectures. You will not be allowed to proceed to the next lecture until you have made at least one attempt for the preceding quiz. You are allowed two attempts, and your grade for each quiz will be the average of your attempts. All quiz attempts must be completed by 11:59 PM on Monday of the following week. Thus, Week Two's quiz attempts must be completed before 11:59 PM on Monday of Week Three. Quizzes not attempted by the due date will receive 0 points. Most quizzes are graded immediately. Some quizzes include brief essays and will be graded within 24 hours.

**Exams:** There are two mid-term exams and one final exam. The exams will be online and will be similar in format to the quizzes. The exams are scheduled for Thursday evening 6-8 PM in the 3rd, 6th, and 8th weeks of the course. Please identify conflicts at your earliest opportunity, and we can work together to arrange an alternate time. Grades on Exams will be available within 24 hours of all students having completed the exam. Also, for each Exam, there will be Pre- and Post-Exam Discussion Fora. The Post-Exam Discussion will include a summary of each problem.

**Make-Up Policy:** There are no make-up homework assignments. If you miss the assignment, you get a zero for it. If you cannot make an exam or other due date, you must contact me *before* the due date. Without prior arrangement, there will be no make-up.

**Grading Policy:**

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|---|---|
| Discussions | 10% |
| Quizzes | 15% |
| Homework | 15% |
| Midterm Exam I | 15% |
| Midterm Exam II | 15% |
| Final Exam | 20% |
| Wild Card | 10% |

The "wild card" 10% is added to the grade for Midterm Exam I or II or Final Exam, whichever is highest. For example, if you have higher grade on Final Exam than for any other Exam, then your Final Exam will count for 30% instead of 20%.

**Grading Scale:** The grading scale is given below, where the numbers are the percentage of the total weighted grades as defined in the Grading Policy above.

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|---|---|
| 98-100 | A+ |
| 93-97.99 | A |
| 90-92.99 | A- |
| 87-89.99 | B+ |
| 83-86.99 | B |
| 80-82.99 | B- |
| 77-79.99 | C+ |
| 73-76.99 | C |
| 70-72.99 | C- |
| 67-69.99 | D+ |
| 63-66.99 | D |

| | |
|---|---|
| 60-62.99 | D- |
| Below 60 | F |

**Attendance Policy:** Regular and punctual attendance is required. UNM Pathfinder policies apply, which in part means instructor drops based on non-attendance are possible. This policy applies regardless of the grading option you have chosen. UNM Learn automatically records all students' activities including: your first and last access to the course, the pages you have accessed, the number of discussion messages you have read and sent, web conferencing discussion text, and posted discussion topics. I access this data regularly to evaluate class participation and to identify students having difficulty. If you are "absent" from the course for three consecutive days, I will contact you. If you are "absent" from the course for one full week, I will contact you about dropping from the course.

**Drop Policy:** This course falls under all UNM policies for last day to drop courses, etc. Please see
http://www.unm.edu/studentinfo.html
or the UNM Course Catalog for information on UNM services and policies. Please see the UNM academic calendar for course dates, the last day to drop courses without penalty, and for financial disenrollment dates.

**Academic Honesty:** The University of New Mexico believes that academic honesty is a foundation principle for personal and academic development. All University policies regarding academic honesty apply to this course. Academic dishonesty includes, but is not limited to, cheating or copying, plagiarism (claiming credit for the words or works of another from any type of source such as print, Internet or electronic database, or failing to cite the source), fabricating information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of another person or work previously used without informing the instructor, or tampering with the academic work of other students. The University's full statement on academic honesty and the consequences for failure to comply is available in the college catalog and in the *Pathfinder*.

**Topics:** (text reference) *Learning Outcomes*

**Introduction and Overview of Attitude Control Concepts (Ch. 1, Lecture slides)**

*Students can identify the principal characteristics, applications, advantages and disadvantages of various attitude control concepts.*

**Review of Basic Orbital Dynamics and Mission Analysis (App. A, Ch. 2, Lecture slides)**

*Students can apply basic features of the two-body problem and its solution.*
*Students can describe the geometry of space mission analysis.*
*Students can apply space mission analysis to attitude determination and control subsystem requirements and design.*

**Review of Particle Dynamics (Lecture Slides)**

*Students can apply inertial and rotating reference frames to particle kinematics.*
*Students can apply Newton's Second Law to derive equations of motion for particles.*

**Attitude Kinematics (Ch. 3)**

*Students can describe attitude kinematics using reference frames, rotation matrices, Euler parameters, Euler angles, and quaternions.*
*Students can accurately perform attitude kinematics calculations.*

**Attitude Determination (Ch. 4)**

*Students can describe the measurements required to determine the attitude of a spacecraft.*
*Students can apply attitude determination algorithms, including TRIAD, q-method, and QUEST.*

**Rigid Body Dynamics (Ch. 5)**

*Students can derive and explain the equations of motion for rigid bodies, including modeling assumptions, angular momentum, Euler's equations, and moments of inertia*
*Students can apply the solutions for an axisymmetric body.*

**Satellite Attitude Dynamics (Ch. 6 and Lecture Slides)**

*Students can describe the environmental forces and moments affecting satellite motion.*
*Students can apply basic dynamics analysis to the attitude dynamics of spin, dual-spin, three-axis, and gravity gradient stabilized satellites, including the effects of energy dissipation.*

**Attitude Control (Lecture Slides)**

*Students can apply linear control theory to attitude control problems.*

**Schedule of Topics:**

**Week One:** *Introduction and Overview of Attitude Control Concepts; Review of Basic Orbital Dynamics and Mission Analysis*

**Week Two:** *Review of Particle Dynamics; Attitude Kinematics*

**Week Three:** *Attitude Kinematics; Exam 1 (Thursday 6-8 PM online)*

**Week Four:** *Attitude Determination*

**Week Five:** *Rigid Body Dynamics*

**Week Six:** *Rigid Body Dynamics; Exam 2 (Thursday 6-8 PM online)*

**Week Seven:** *Satellite Dynamics*

**Week Eight:** *Satellite Attitude Control; Final Exam (Thursday 6-8 PM online)*

**Other Spacecraft Dynamics Books:**

- Bate, Mueller, & White, *Fundamentals of Astrodynamics*, Dover, 1971. An excellent and affordable treatment of astrodynamics.
- P. C. Hughes, *Spacecraft Attitude Dynamics*, 2004, Dover. This is an excellent text on the attitude dynamics (no control) of rigid and "quasi-rigid" spacecraft, especially the stability analysis. The author uses vector and tensor notation extensively. This inexpensive Dover edition is a reprint of the 1986 Wiley edition.
- H. Schaub and J. L. Junkins, *Analytical Mechanics of Space Systems*, 2003, AIAA. Provides a comprehensive treatment of dynamics of space systems beginning with the fundamentals.
- M. J. Sidi, *Spacecraft Dynamics and Control*, 1997, Cambridge. A "practical engineering approach" to both orbital and attitude dynamics and control.

- W. T. Thomson, *Introduction to Space Dynamics*, 1986, Dover. An excellent and affordable introduction to a variety of topics in spacecraft dynamics.
- J. R. Wertz, editor, *Spacecraft Attitude Determination and Control*, 1978, D. Reidel. This is a monumental tome written by many people. It is quite application-oriented, with many examples.
- B. Wie, *Space Vehicle Dynamics and Control*, AIAA, 1998. This book includes in-depth coverage of classical and modern control theory, as well as development of many important topics in both orbit and attitude dynamics.
- W. E. Wiesel, *Spaceflight Dynamics*, McGraw-Hill, 2nd edition, 1997

**Accommodation Statement:** Accessibility Services (Mesa Vista Hall 2021, 277-3506) provides academic support to students who have disabilities. If you think you need alternative accessible formats for undertaking and completing coursework, you should contact this service right away to assure your needs are met in a timely manner. If you need local assistance in contacting Accessibility Services, see the Bachelor and Graduate Programs office.

**Title IX Statement:** In an effort to meet obligations under Title IX, UNM faculty, Teaching Assistants, and Graduate Assistants are considered "responsible employees" by the Department of Education (see pg 15 of http://www2.ed.gov/about/offices/list/ocr/docs/qa-201404-title-ix.pdf). This designation requires that any report of gender discrimination that includes sexual harassment, sexual misconduct and sexual violence made to a faculty member, TA, or GA must be reported to the Title IX Coordinator at the Office of Equal Opportunity (oeo.unm.edu). For more information on the campus policy regarding sexual misconduct, see: https://policy.unm.edu/university-policies/2000/2740.html

**UNM Resources:**

**CAPS Tutoring Services** http://caps.unm.edu/programs/online-tutoring/
CAPS is a free-of-charge educational assistance program available to UNM students enrolled in classes. Online services include the Online Writing Lab, Chatting with or asking a question of a Tutor.

**UNM Libraries** http://library.unm.edu

**Student Health & Counseling (SHAC) Online Services**
http://online.unm.edu/help/learn/support/shac