# MAE 476 – Space Flight and Systems – Spring 2022

Department of Mechanical and Aerospace Engineering

West Virginia University

| | |
|---|---|
| INSTRUCTOR: | Dr. Andrew Rhodes<br>Office: ESB 829<br>Email: Andrew.Rhodes@mail.wvu.edu |
| CLASS: | Schedule: M/W/F 9:00-9:50<br>Location: ESB G102<br>Credit: 3 hours |
| PREREQUISITE: | MAE 316 Analysis of Engineering Systems<br>Grade: D- or better |
| TEXTBOOK: | Recommended Reference:<br>*Orbital Mechanics for Engineering Students, 4th Ed, by Curtis.*<br>eBook available through WVU Library. |
| DESCRIPTION | Introduction to fundamental concepts of space flight and vehicles, emphasizing performance aspects and basic analytical expressions. Common analysis methods and design criteria for launch vehicles, orbital mechanics, atmospheric re-entry, stabilization, thermal, power, and attitude control. |
| TECHNOLOGY: | Webcam, digital/phone scanner, and internet access required.<br>MATLAB 2021 or newer, free through WVU<br>(https://its.statler.wvu.edu/policies-and-procedures/matlab-software) |
| TEACHING ASSISTANT | Sam Cyphert<br>Office: Zoom https://wvu.zoom.us/j/95383482769<br>Email: sc0120@mix.wvu.edu |
| OFFICE HOURS: | Office hours are conducted in-person, via email, or video or voice calls.<br>*Instructor:* MW 11:00-13:00<br>*Assistant:* R 14:00-15:00<br>If the instructor or assistant is not available at these times, then substitute times will be allotted in the same week. |

GRADING:

| | |
|---|---|
| Homework | 25% |
| Quiz | 10% |
| Midterm Design Project | 15% |
| Final Design Project | 15% |
| Midterm Exam | 15% |
| Final Exam | 15% |
| *Floating Exam Credit* | 5% |

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

## TENTATIVE COURSE SCHEDULE

| Week | Dates | Lecture Topic | Book Sections | Notes & Assignments |
|---|---|---|---|---|
| 1 | 1/10 | Intro. to Space Flight and Systems. | | |
| | 1/12 | Fundamentals of Orbital Mechanics I. | §2.1-2.3, Handout | |
| | 1/14 | Fundamentals of Orbital Mechanics II. | §2.4-2.5 | |
| 2 | 1/17 | **MLK JR Day** (No Class**)** | | |
| | 1/19 | Orbital Period. Canonical Units. | §2.6-2.7, Handout | HW 1 Due. |
| | 1/21 | Time of Flight. | §3.1-3.4, §2.10 | Quiz 1. |
| 3 | 1/24 | Coordinate Systems. | §5.5-5.7, Handout | |
| | 1/26 | Coordinate Frame Transformations. | | |
| | 1/28 | Orbital Elements I. | §4.4 | HW 2 Due. Quiz 2. |
| 4 | 1/31 | Orbital Elements II. | | orbitalmechanics.info |
| | 2/2 | Orbital Elements III. | | agi.com/products/stk |
| | 2/4 | Keplerian Orbit Propagation I. | §3.1-3.4 | HW 3 Due. |
| 5 | 2/7 | ~~**Non-Instructional Day** (No Class)~~ | | |
| | 2/9 | Keplerian Orbit Propagation II. | | |
| | 2/11 | Numeric Orbit Propagation. | | |
| 6 | 2/14 | Timekeeping. | §5.4 | |
| | 2/16 | Ground Track I. | §4.7 | HW 4 Due. Quiz 3. |
| | 2/18 | Ground Track II. | | |
| 7 | 2/21 | Preliminary Orbit Determination. | §5.1-5.2. Handout | |
| | 2/23 | Review. | | HW 5 Due. |
| | 2/25 | **Midterm Exam** | | |
| 8 | 2/28 | Analytic Orbit Perturbations I. | §4.7, §10.4-10.5 | |
| | 3/2 | Analytic Orbit Perturbations II. | | |
| | 3/4 | Numeric Orbit Perturbations. | Handout. | **Midterm Grades Due** |
| 9 | 3/7 | Coplanar Maneuvers I. | §6.1-6.3 | |
| | 3/9 | Rendezvous I. | | |
| | 3/11 | Rendezvous II. Synodic Period. | §6.5, §6.8 | Midterm Project Due. Quiz 4. |
| 10 | 3/14-3/18 | **Spring Recess** (No Class) | | |
| 11 | 3/21 | Plane Changes I. | §6.9 | |
| | 3/23 | Plane Changes II. | | |
| | 3/25 | Rocket Propulsion Basics. | | |
| 12 | 3/28 | Non-impulsive Orbital Maneuvers | §6.10 | |
| | 3/30 | Interplanetary Travel. | §8.1-8.4 | |
| | 4/1 | Patched Conic Approximation I. | §8.5-8.6 | HW 6 Due. Quiz 5. |

| Week | Dates | Lecture Topic | Book Sections | Notes & Assignments |
|---|---|---|---|---|
| 13 | 4/4 | Patched Conic Approximation II. | §8.8 | |
| | 4/6 | Patched Conic Approximation III. | | |
| | 4/8 | Gravity Assist Maneuvers I. | §13.3-13.4 | |
| 14 | 4/11 | Gravity Assist Maneuvers II. | | HW 7 Due. Quiz 6. |
| | 4/13 | Launch Windows and Time. | §8.9 | |
| | 4/15 | **Spring Holiday** (No Class) | | |
| 15 | 4/18 | Launch Geometry. | | |
| | 4/20 | Launch Velocity. | | |
| | 4/22 | Multi-Stage Launch Vehicles. | §13.5 | |
| 16 | 4/25 | Spacecraft End-of-Life. | | HW 8 Due. Quiz 7. |
| | 4/27 | Spacecraft Subsystems. | | |
| | 4/29 | Review. | | Final Project Due |
| 17 | 5/3 | **Final Exam** | | 2:00 – 4:00 pm |

## COURSE & STUDENT OUTCOMES

This is a key course for Student Outcomes 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 |
|---|---|
| Identify and describe orbital elements and their relation to spacecraft position and motion. | 1 |
| Calculate the flight path of a spacecraft. | 1 |
| Implement numerical propagation techniques of spacecraft motion in software. | 1 |
| Describe historic and contemporary spaceflight events and their impact on society. | 4 |
| Discuss the professional responsibility of engineers in spaceflight. | 4 |
| Work in teams to design orbital mechanics and interplanetary mission applications. | 2, 5 |

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.
5. The ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

## 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 these polices. Listed below are particular policies that I wish to emphasize.

## 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 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, 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 applicable and wear the required PPE. Should a student forget to bring the required PPE, PPE will be available in the building for students to acquire students who fail to comply will be dismissed from the classroom for the class period and may be referred to the Office of Student Conduct for further sanctions. If a student becomes sick or is required to quarantine during the semester, they should notify the instructor. The student should work with the instructor to develop a plan to receive the necessary course content, activities, and assessments to complete the course learning outcomes.

## 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/coursecreditstermsclassi_cation). 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

| 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.<br>Grade of zero on the entire minor course element.<br>Possible one-letter reduction in final grade. |
| 2 | Cheating or plagiarism on a major course element (e.g. exam, project). | Report of academic dishonesty.<br>Grade of zero on the entire major course element.<br>Possible additional one-letter reduction in final grade.<br>Possible UF recommendation.<br>Possible exclusion from further participation in class. |
| 3 | Collusion on major course element. | Report of academic dishonesty.<br>Exclusion from further participation in class.<br>Failure of the course.<br>Recommendation for UF. |
| 4 | Other (document alteration, tampering with records, etc.). | Report of academic dishonesty.<br>Grade of zero on the entire major course element.<br>Possible additional one-letter reduction in final grade.<br>Possible failure in the course.<br>Possible exclusion from further participation in the class.<br>Possible UF recommendation. |

| |
|---|
| UF– Unforgivable F Grade, cannot be replace under D-F repeat policy.<br>Dismissal from the Statler College is permanent for Academic Integrity violations. Student conduct violations can be considered dismissal.<br>Separable sanctions (e.g. dismissal from Statler College, suspension, or expulsion from WVU) will be recommended for aggravated or second Academic Integrity offenses.<br>Warning letters may be issued from the Statler College or the WVU Office of Stud |
| 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. |
| FORBIDDEN on Exams and Quizzes: 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. |