

MAE 484 – Spacecraft Propulsion – Spring 2022

Department of Mechanical and Aerospace Engineering
West Virginia University

<u>INSTRUCTOR:</u>	Dr. Andrew Rhodes, Teaching Assistant Professor Office: ESB 829 Email: Andrew.Rhodes@mail.wvu.edu														
<u>CLASS:</u>	Schedule: M/W/F 10:00-10:50 Location: ESB 801 Credit: 3 hours														
<u>PREREQUISITE:</u>	MAE 336 Compressible Aerodynamics Grade: D- or better														
<u>DESCRIPTION</u>	Brief introduction to aircraft propulsion including turbojets. Introduction to rocket and spacecraft propulsion. The rocket equation, staging, liquid rocket engines and solid rocket motors, thermochemistry, and combustion.														
<u>TEXTBOOK:</u>	Recommended References: <i>Rocket Propulsion Elements</i> , 8 th or 9 th Ed., by Sutton and Biblarz. Publisher: Wiley eBook available through WVU Library														
<u>TECHNOLOGY:</u>	Webcam, digital/phone scanner, and internet access required. MATLAB 2020 or newer (https://its.statler.wvu.edu/policies-and-procedures/matlab-software)														
<u>OFFICE HOURS:</u>	Office hours are conducted virtually via email, video or voice calls, or forum discussions. <i>Instructor:</i> M/W 11:00-13:00 If the instructor is not available at these times, then substitute times will be allotted in the same week.														
<u>GRADING:</u>	<table><tr><td>Homework</td><td>25%</td></tr><tr><td>Project</td><td>15%</td></tr><tr><td>Quiz</td><td>10%</td></tr><tr><td>Exam 1</td><td>15%</td></tr><tr><td>Exam 2</td><td>15%</td></tr><tr><td>Final Exam</td><td>15%</td></tr><tr><td><i>Floating Exam Credit</i></td><td>5%</td></tr></table>	Homework	25%	Project	15%	Quiz	10%	Exam 1	15%	Exam 2	15%	Final Exam	15%	<i>Floating Exam Credit</i>	5%
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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	Introduction to Spacecraft Propulsion.		
	1/12	Rocket Propulsion Fundamentals I.	§2.2-2.3, Handout.	
	1/14	Rocket Propulsion Fundamentals II.		
2	1/17	MLK Day (No Class)		
	1/19	Tsiolkovsky Rocket Equation.	§3.1	
	1/21	Launch Trajectory. Velocity Budgets.	Handout	HW 1 Due
3	1/24	Space Flight.	§4.4, Handout	Quiz 1
	1/26	Atmospheric Models.	§4.1-4.3, Handout.	
	1/28	Trajectory Equations.	Handout	
4	1/31	Numeric Trajectory Propagation.		
	2/2	Multistage Launch Vehicles.	§4.7, Handout	HW 2 Due
	2/4	Series Multistage Vehicles.	Handout	Quiz 2
5	2/7	Parallel Multistage Vehicles.		
	2/9	Thermodynamics Fundamentals.	§3.2	
	2/11	Isentropic Flow.		
6	2/14	Isentropic Nozzle Flow.	§3.3, Handout	HW 3 Due
	2/16	Thermodynamic Thrust.	Handout	Quiz 3
	2/18	Review.		
7	2/21	Exam 1		
	2/23	Nozzle Expansion and Separation.		
	2/25	Introduction to Thermochemistry.	§5.1-5.2 Humble Ch. 4	
8	2/28	Thermochemistry Basics.		HW 4 Due
	3/2	Minimization of Free Energy.		janaf.nist.gov https://webbook.nist.gov/
	3/4	Available Heat Method.		Midterm Grades Due
9	3/7	Chemical Equilibrium with Applications (CEA).		cearun.grc.nasa.gov
	3/9	Thermochemistry Examples.		
	3/11	Liquid Propellants.	§7.1-7.4	Quiz 4
10	3/14-3/18	Spring Recess (No Class)		
11	3/21	Real Nozzles.	§3.4-3.5	
	3/23	Nozzle Dimensions.	Rezende Ch. 5, 7	
	3/25	Chamber Dimensions.	§8.2 Rezende Ch. 6	HW 5 Due
12	3/28	Propellant Tanks.	§6.2	
	3/30	Review		
	4/1	Exam 2		

Week	Dates	Lecture Topic	Book Sections	Notes & Assignments
13	4/4	Injectors.	§8.1 Rezende Ch. 9	
	4/6	Simplex Swirl Injector. Pintle Injector.	Rezende Ch. 10, 11	
	4/8	Chamber Cooling I.	§8.5	
14	4/11	Chamber Cooling II.		HW 6 Due
	4/13	Engine Cycles.		Quiz 5
	4/15	Spring Holiday (No Class)		
15	4/18	Turbopumps I.	§10.1-10.6	
	4/20	Turbopumps II.		HW 7 Due
	4/22	Gas Pressure Feed Systems.	§6.4-6.5	Quiz 6
16	4/25	Solid Rocket Motors (SRM).	§12.1	
	4/27	Electric Propulsion Systems.	§17	
	4/29	Solar Lightsail Propulsion.	Vulpetti	Project Due
17	5/5	Final Exam		2:00 – 4:00 pm

COURSE & STUDENT OUTCOMES

This is a key course for Student Outcomes 1, 2, 4, and 5. 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
Formulate and solve fundamental problems in rocket propulsion using thermochemistry.	1
Analyze and design supersonic rocket nozzles at specified operational altitudes.	2
Design multi-stage launch vehicles to deliver a payload to specified orbits.	2
Recognize and describe historic and contemporary launch vehicle systems.	4
Work in teams to complete a preliminary sizing of a launch vehicle and liquid rocket engine.	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. An 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 policies. 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/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

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.

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

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

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 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.