Last Revised: 11/17/2020

The University of Texas at San Antonio
Department of Mechanical Engineering
ME 4953/ME 5013 Propulsion
Syllabus

Part A – Course Outline

Course Description:
(3-0) 3 Credit Hours.
Application of thermodynamics and fluid mechanics to the analysis of problems related to propulsion of aerospace vehicles. Development of control volume analysis techniques for compressible flow problems, with applications in the design and analysis of rocket nozzles and state-of-the-art propulsion systems like ramjets, scramjets, and detonation cycle systems.

Prerequisites:
ME 3293 - Thermodynamics I
ME 3663 - Fluid Mechanics

Recommended textbook:
Hill & Peterson, *Mechanics and Thermodynamics of Propulsion, 2nd Edition*, Pearson

Major prerequisites by topic:
1. Differential and integral calculus
2. Principles of fluid mechanics
3. Control volume analysis
4. Principles of thermodynamics

Topics Covered:
1. Classification of Rocket and Aircraft Propulsion Systems
2. 1D Compressible Flow: Rayleigh, Fanno flow, shock waves
3. Characteristic Propulsive Properties: Thrust, characteristic velocity, nozzles
4. Combustion and thermochemistry: Chemical thermodynamics, fuels
5. Liquid rocket engine systems: Monopropellants, bipropellants, pumps, injectors
6. Solid rocket motor systems: burn rates, specific impulse, sizing, stability
7. Hybrid rocket motor systems: heat transfer, regression rates, modeling
8. Mission and trajectory analysis: Launch vehicles, missiles, multistage rockets
9. Detonation-based propulsion: pulsed detonation and rotating detonation engines

Contribution of course to meet the professional component:
This course builds the foundation for preparing students to work professionally in the area of thermal-fluid systems with a fundamental understanding of compressible flow.

Last Revised: 11/17/2020

Relationship of course to Student Outcomes:
This course primarily contributes to Mechanical Engineering program student outcomes:
1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

7.* an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

* This student outcome is both covered and assessed as part of the Mechanical engineering department continuous improvement process.

Course Objectives (contribution to Student Outcomes):
For students to demonstrate
1. Fundamental understanding of compressible flow phenomena (1, 7)
2. Ability to complete basic isentropic flow calculations (l, 7)
3. Ability to predict the impact of heating and friction on a compressible flow (1, 7)
4. Knowledge of some topics from orbital mechanics and rocket propulsion (1,7)
5. Ability to perform mixing and combustion calculations (1,7)
6. Develop skills necessary to support life-long learning through researching information to respond to questions posed in lecture and laboratory classes (1)

Course Coordinator: Daniel I. Pineda

Person(s) who prepared/revised this description:
Daniel I. Pineda, November 2020
Daniel I. Pineda, August 2020

Last Revised: 11/17/2020

The University of Texas at San Antonio
Department of Mechanical Engineering
ME 4953/ME 5013 Propulsion
Syllabus

Part B – General Course Information

Instructor: Daniel I. Pineda, Ph.D.
Office: EB 3.04.12
E-mail: daniel.pineda@utsa.edu
Office Hours: M: 10a–11a; W: 2p–3p; Th: 10a–11a

Time: Lecture: Online, MW 4:00-5:15pm; recordings posted online after

Location: Lecture: Virtual (Zoom)

Grading:

Undergraduates (ME 4953):	Graduates (ME 5013):
20% Homework	15% Homework
35% Midterm Exams	25% Midterm Exams
45% Final Exam	20% Written Project
	40% Final Exam

Homework Assignments:
Assigned approximately weekly (posted on course website), with solutions posted after due date. Late assignments cannot be accepted, as solutions will be posted after class on the due date. If extenuating circumstances arise, please contact Prof. Pineda.

Students are allowed to collaborate with each other on homework, and in fact are encouraged to do so. However, if a homework solution is turned in that is identical or virtually identical to the solution turned in by another student, neither student will receive credit for the solution to that problem. In this case it will be impossible to tell who really worked the problem.

Website:
UTSA – Blackboard: ME 4953/ME 5013 Propulsion

Required texts:
Hill & Peterson, *Mechanics and Thermodynamics of Propulsion, 2nd Edition*, Pearson
ISBN: 978-0201146592
Course Notes (available on Blackboard) to supplement portions of course material

Additional Refs (On reserve)**:**
Rocket Propulsion Elements by G. Sutton
Space Propulsion Analysis and Design by Humble, Henry, and Larson

Attendance:
In an effort to make course material equitably accessible to all students during the COVID-19 pandemic, synchronous attendance in this class is not mandatory, and any live lectures will be recorded and posted online for later viewing. Students who attend lectures via Zoom will often have the chance to ask questions live, and some lectures will specifically review course material before exams. Each student is responsible to be aware of ALL announcements made in class, in addition to being responsible for learning ALL of the material covered and discussed in class and the material noted as readings in the course text. Hence, it's a good idea to just attend every class session if you can. Note that the provided Course Notes only contain a relatively small fraction of the total material covered in this course. Critical announcements will be placed on the class web page; please check this page frequently.

Exam Policy:
The midterm exam will be a take-home test posted on Blackboard or emailed to students. Additional considerations for the exam will be posted/sent with the exam instructions.

Make-up Exams:
Make-up exams will not be allowed unless previously approved by the instructor.

Excused Absences:
Excused absences include personal illnesses, deaths in the family, religious holidays, and UTSA sponsored activities. For illnesses, you must provide documentation (physician's statement/note, etc.) within 3 class meetings in order to be excused. Absences in observance of religious holidays are authorized only if you notify your instructor in writing (email or physical note) at least one week in advance. UTSA sponsored events require an original signed letter on UTSA letterhead from the faculty or staff sponsor.

Extra Credit
Any potential extra credit opportunities will be offered by the instructor to the class as a whole and will never be offered exclusively to individual students hoping to improve their grade. Solicitations by students for extra credit opportunities will not be provided with a response, given that this action would violate UTSA policy by promoting differential treatment between students.

Scholastic Dishonesty:
Scholastic dishonesty is a serious offense that includes, but is not limited to, copying homework, cheating on a test, plagiarism, or collusion. The Office of Student Life (210-458-4720) should be contacted if a student has questions about what constitutes scholastic dishonesty:
http://utsa.edu/studentlife/conduct/scholastic_dishonesty.html

While it is acceptable to look at other students' assignments for the purpose of seeing the format and style, it is a violation of University policy to plagiarize (copy) text from other students' work without proper citation. Figures must also be original.

Cases of suspected scholastic dishonesty related to exams and written reports will be prosecuted through the UTSA Office of Student Life, with the recommended penalty that the student receive an "F" grade for the class.

Blackboard:
Many of the material you need for this course will be posted in Blackboard. It is your responsibility to check Blackboard on a regular basis throughout the semester. I may post important messages regarding assignments, schedules, and any changes to the syllabus through Blackboard. These messages may require a response from you. Assignments and quizzes will be posted to Blackboard as well.

To learn how to navigate Blackboard, you can view these tutorials:
https://www.youtube.com/playlist?list=PLontYaReEU1seUE3ACG3sEc3zR7Br7URU

Audio/Video Recording:
Feel free to record any lectures or presentations in class for your own personal use at UTSA. However, these recordings may not be duplicated, shared, or disseminated without the express written consent of the instructor.

University Policies:
Required university policy link:
http://teaching.utsa.edu/wp-content/uploads/2018/07/Required- University-Policies.pdf

Roadrunner's Creed:
https://www.utsa.edu/studentlife/creed.html

Student Support Services:
http://teaching.utsa.edu/wp-content/uploads/2018/07/UTSA-Student-Support-Services.pdf

Responsible Employee Notice:
The University has an obligation to maintain an environment free of sexual harassment and sexual violence, thus many University employees, including the instructor, have mandatory reporting and response obligations and may not be able to honor a complainant's request for confidentiality. Complainants who want to discuss a complaint in strict confidence may use the resources outlined in HOP Section IX.A.5, "Confidential Support and Resources" at the following link:
http://www.utsa.edu/hop/chapter9/9-24.html

Disclaimer:
The course schedule is tentative and may be changed to accommodate campus closures related to weather, ongoing improvements to university online infrastructure, or public health concerns as related to COVID-19. Any corresponding changes to the course schedule will be announced in lecture and online. Students are responsible for staying up to date on these announcements.

Last Revised: 11/17/2020

CLASS PROJECT
ME 5013 Propulsion
Fall 2020

The class project for ME 5013 is designed to give you an opportunity to learn about and/or perform an analysis of a potential future rocket system or concept. Many engineers over the past few decades have proposed and explored rocket systems for either launch or spacecraft systems that, at the time, were viewed as revolutionary, starting, in fact with Robert Goddard's pioneering liquid-fueled rocket from the 1920s. Today there are a range of chemical and non-chemical rocket systems available, but what are the future directions for the field, either 'evolutionary' or 'revolutionary.'

Students will **work in pairs** on this project. With your partner you will choose a topic, research the topic via a short literature search, and then focus on either one of the following:

An **analysis via a single paper or a literature survey of the topic or concept in question**, assessing what has been conducted on the topic or concept, the major features of the study (methods, findings, conclusions), and your ideas on futures directions for the topic or concept **OR**

A **simple model for the concept or topic in question**, developed using the analysis tools we have learned in this class, and then evolving predictions of performance parameters associated with the concept, ways to optimize performance, and recommendations for future directions.

The output for this project with be a **written report** of about 5 pages in length (not including appendices, which could include details of the analysis, etc.). A rough timetable for the project is as follows:

- Wednesday, September 9: Choose your partner
- Wednesday, September 16: Choose your tentative topic and report both the topic and your partner to me
- Friday, November 20: Written report due

More information on the details for the written presentations will be provided in the near future. One source of technical concepts and studies in propulsion is the AIAA **Journal of Propulsion and Power**, for which abstracts are available online.

Here are some of the many possible topics you could choose:

- Detonation-based rocket concepts
- Advanced propellants (liquid, solid, gas, or multi-phase)
- Combined cycle engines (may include air-breathing) w/ comparison to conventional rockets
- Alternative designs for rocket components (injectors, nozzles, fuel grains, turbopumps, etc.)
- Advanced control systems (e.g. for combustion instability, thrust vector control, sensors etc.)
- Advanced electric or magnetoplasma thrusters

Last Revised: 11/17/2020

TENTATIVE COURSE OUTLINE AND SCHEDULE
ME 4953/ME 5013 Propulsion
D.I. Pineda, Fall 2020

(Reference Key: HP = Hill and Peterson text; Course Notes = Course Notes by Prof. Pineda)

Lect. (No.)	Date (tent.)	Topics (general)	References		HW Due
			HP	Course Notes	
1	M, 08/24	**Introduction** Classification of rocket prop systems History, applications of rocket systems	 Ch. 1 Ch. 1	 X X	
2	W, 08/26	**Review topics:** Conservation equations I Rocket equation	 2.2 10.3	 X	
3	M, 08/31	Conservation equations II Thermodynamic relations	2.2 2.2, 2.3	X X	HW#1
4	W, 09/02	1D compressible flow I	3.1–3.3	X	
	M, 09/07	Labor Day Holiday – No Class			
5	W, 09/09	1D compressible flow II	3.5, 3.6		HW#2
6	M, 09/14	1D compressible flow III	3.7	X	
7	W, 09/16	1D compressible flow IV	11.3	X	HW#3
8	M, 09/21	**Characteristic propulsive properties:** Characteristic properties I	10.2, 10.3, 11.2		
	W, 09/23	**MIDTERM EXAM #1** Timed Take-Home Exam Covers thru 1D compressible flow			
9	M, 09/28	Characteristic properties II	11.3		
10	W, 09/30	**Combustion and thermochemistry:** Combustion chemistry I			
11	M, 10/05	Combustion chemistry II	2.3, 2.4		HW#4
12	W, 10/07	Combustion chemistry III	2.4		
13	M, 10/12	Combustion chemistry IV Rocket fuels and propellants	2.4		HW#5
14	W, 10/14	**Liquid Rocket Engine (LRE) systems** Introduction, operation Monopropellants, bipropellants	 12.2 12.2		

15	M, 10/19	LRE Components Cycle analysis I	12.5 13.2, 13.3		
16	W, 10/21	Nozzle chemistry, injectors Cycle analysis II	12.3–12.5		HW#6
17	M, 10/26	**Solid Rocket Motor (SRM) systems:** Intro, burn rates, Isp SRM components	 12.6 12.6, 12.7		
	W, 10/28	**MIDTERM EXAM #2** Timed Take-Home Exam + Project Covers through LRE systems			
18	M, 11/02	Thrust vector control, sizing Chamber pressure variation SRM stability, erosive burning	 12.6, 12.7 12.6, 12.7		
19	W, 11/04	**Hybrid Rocket systems:** Review: heat transfer mechanisms Introduction	 4.5, 11.4		
20	M, 11/09	Hybrid rocket models, burning rates Components			
21	W, 11/11	**Mission & trajectory analysis:** Launch vehicles Upper stage/ OTVs	 10.6		HW#7
22	M, 11/16	Orbital Mechanics Ballistic missiles, interceptors	10.6		
23	W, 11/18	Vertical trajectories Multistage rockets	10.4		
24	M, 11/23	Guest Lecture (Dr. F. Bendana, Aerospace Corp): Hybrid Rocket Combustion			HW#8
25	W, 11/25	Guest Lecture (Dr. L. Paxton, Relativity Space): Additively Manufactured Propulsion			
26	M, 11/30	**Future/alternative space propulsion:** Detonation Engines I			
27	W, 12/02	Detonation Engines II Final Exam Review			
	12/07	**FINAL EXAM**: 3:00–4:50 PM Timed Take-Home Exam Comprehensive			