Last Revised: 10/21/2021

The University of Texas at San Antonio
Department of Mechanical Engineering
ME 5663 Gas Dynamics
Syllabus

Course Description:
(2-3) 3 Credit Hours.
Integral and differential forms of the conservation equations, one-dimensional flow, oblique shock and expansion waves, supersonic, transonic, and hypersonic flows. Microscopic view of thermophysical properties of gases.

Prerequisites:
Graduate standing and consent of instructor.

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

Time: Lecture: TR 4:00-5:15pm; recordings posted online after

Location: Lecture: Online (Zoom, first 3 weeks[1]); AET 0.102 thereafter

Required Texts:
Anderson, J.D., *Modern Compressible Flow*, 3rd or 4th Edition, McGraw-Hill
Vinceti, W.G., Kruger, C.H., *Introduction to Physical Gas Dynamics*, John Wiley & Sons

Major Prerequisites by topic:
1. Differential and Integral Calculus
2. Fluid Dynamics
3. Thermodynamics

Topics Covered:
1. Compressible Conservation Equations, Rayleigh/Fanno Flow
2. Normal/Oblique Shocks and Expansion Fans
3. Shock Reflections and Intersections
4. Area-velocity relationship and nozzles
5. Unsteady wave motion
6. Method of characteristics
7. Hypersonic Flows
8. Compressible Boundary Layers
9. Kinetic Theory Interpretation of Macroscopic Gas Properties
10. High-Temperature Gas Dynamics
11. Equilibrium Flows
12. Non-equilibrium Flows

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[1] Subject to change in response to evolution of the COVID-19 pandemic, please reference Blackboard for most up-to-date information about course modality

Grading:

30% Homework
20% Midterm Exam
20% Final Exam
30% Final Project

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 5633 Advanced Compressible Flow

Additional Refs (On reserve)**:**
Elements of Gasdynamics by H.W. Liepmann and A. Roshko
Hypersonics and High Temperature Gas Dynamics by J. Anderson

Attendance:
In an effort to make course material equitably accessible to all students during the COVID-19 pandemic, synchronous/in-person attendance in this class is not mandatory, and all live lectures (conducted remotely or in-person) will be recorded and posted online for later viewing. **For the safety and health of everyone, do NOT come to class if you are feeling sick.**

For lectures which are hosted on Zoom (as needed to accommodate new developments in the COVID-19 Pandemic), students 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. This is **not** a course which can be "crammed" at the end of the semester. Note that any provided handouts/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:
Unless required by UTSA policies in response to the COVID-19 pandemic, the midterm and final exams will be given in-person. Additional considerations for the exams will be posted or announced ahead of the exams.

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:
This syllabus is provided for informational purposes regarding anticipated course content and schedule of courses. It is based on the most recent information available on the date of its issuance and is as accurate and complete as possible. I reserve the right to make any changes necessary and/or appropriate and will make every effort to communicate any changes in a timely manner in class. Students are responsible for staying up to date on any changes to the syllabus that may occur during the term of this course.

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CLASS PROJECT
ME 5633 Gas Dynamics
Fall 2021

The class project for ME 5633 is designed to give you an opportunity to learn about and/or perform an analysis of an experiment which creates hypersonic and/or high temperature flow conditions in a laboratory environment. Many scientists and engineers over the past few decades have developed several canonical experimental configurations which can create environments that are comparable to the idealized models we will develop and discuss in this course.

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

An **unsteady computational model for the device in question (written in either MATLAB or Python)**, 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 outputs 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.) **along with a submitted zip file/archive of a self-contained computer code** which can run in MATLAB 7 or later or Python 3 or later. The code should output the time-evolution of your chosen system (e.g., x-t diagram, time-stepped 2D contour plots, etc.). The code should be thoroughly commented and equations from the course textbook(s) should be referenced in the code comments. Code output alone will not suffice for this requirement.

All code should be **original work** and flexibly accommodate any perfect gas mixture (via adjustable specific heat ratio γ and molecular weight M) at any initial temperature and pressure for which perfect gas relations hold throughout the experiment. Your code need not accommodate non-idealities, but the implications of any non-idealities should be discussed in your written report.

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
- Wednesday, November 18: Written report and code due

More information on the details for the written reports will be provided in the near future.

Here are some of the many possible canonical compressible flow devices you could choose:

- Shock Tube (1D unsteady)
- Expansion Tube (1D unsteady)
- Ludwieg Tube (2D steady, 2D time-marching, or1D approximation)
- Expansion Tunnel (2D steady, 2D time-marching, or 1D approximation)
- Reflected Shock Tunnel (2D steady, 2D time-marching, or 1D approximation)

If applicable, you are advised to choose a topic closely related to your own research projects to maximize your graduate studies experience.

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TENTATIVE COURSE OUTLINE AND SCHEDULE
ME 5633 Gas Dynamics
D.I. Pineda, Fall 2021

(Reference Key: A = Anderson text; V&K = Vinceti and Kreuger text)

Lect.	Date	Topics	References		HW Due
(No.)	(tent.)	(general)	A	V&K	
1	T, 08/24	**Introduction** Classification of flow regimes Thermo and Compressible Flow Review	1.1–1.3 1.4–1.7		
2	Th, 08/26	**Part I: 1-D Flow** 1D compressible flow: Euler flow Non-isentropic flows, normal shocks	3.1–3.5 3.6–3.7		
3	T, 08/31	Rayleigh and Fanno flow, examples Quasi-1D flow Area-velocity relation	3.8–3.9 5.1–5.5		
4	Th, 09/02	Nozzles and diffusers Example problems			
5	T, 09/07	1D unsteady gas dynamics “linearized” Acoustic theory, speed of sound	7.4–7.6		HW#1
6	Th, 09/09	1-D finite disturbances Method of characteristics: Expansion Wave		VIII.14	
7	T, 09/14	Expansion waves Example Problems			HW#2
8	Th, 09/16	Moving shocks Shock and expansion wave reflection	7.1–7.3		
9	T, 09/21	Shock tube analysis Contact surface interaction Example Problems	7.7–7.9		HW#3
10	Th, 09/23	Reflected Expansion Waves (example) Numerical techniques for 1-D flow			
11	T, 09/28	**Part II: 2-D Flow** Mach waves and oblique shock waves	4.1–4.4		HW#4
12	Th, 09/30	Supersonic flow over wedges and cones Midterm Review			
	T, 10/05	**MIDTERM EXAM** In Class, 4:00 PM Covers through Part I: 1-D Flow			
13	Th, 10/07	Coefficient of pressure Shock polars and reflections	4.5–4.6		
14	T, 10/12	Oblique Shock Intersections	4.7–4.11		
15	Th, 10/14	Prandtl-Meyer Expansion/Compression Shock Expansion Theory	4.14–4.15		
16	T, 10/19	Numerical techniques for 2-D flow Midterm discussion	11.1–11.7		HW#5
17	Th, 10/21	Hypersonic Flows, Shock Wave Relations Mach Number Independence	15.1–15.3 15.5		
18	T, 10/26	Compressible Boundary Layers Shock Wave/Boundary Layer Interactions			
19	Th, 10/28	Compressible Flow Facility Types Design considerations			HW#6

20	T, 11/02	**Part III: Molecular Gas Dynamics** Kinetic theory of gases Temperature, Kinetic Energy Gas Pressure		I.1–I.2 I.3	
21	Th, 11/04	Collision processes, frequency Cross-section, mean free path		I.4	
22	T, 11/09	Equipartition of energy Velocity distributions	16.2	II.2–II.3, II.5–II.6	HW#7
23	Th, 11/11	Introduction to statistical mechanics Quantum energy states Boltzmann energy distribution	16.2–16.4 16.5	IV.1–3 IV.3 IV.4–IV.6	
24	T, 11/16	Partition functions Thermodynamic properties	16.6–16.8	IV.7–IV.8	
25	Th, 11/18	Chemical equilibrium Non-equilibrium considerations High temperature flows	16.9–16.2 16.13,17.10 17		
	T, 11/23	**FALL 2021 TECH SYMPOSIUM** No Class			
	Th, 11/25	**THANKSGIVING** No Class			
26	T, 11/30	Advanced experimental measurements in compressible flows			
27	Th, 12/02	Final Exam Review			HW#8
	T, 12/07	**FINAL EXAM**: 3:00–4:50 PM Location TBD			