TEXAS A&M UNIVERSITY
Department of Mechanical Engineering

# MEEN 472-500 Gas Dynamics
# Fall 2012

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| **Instructor:** | Dr. Eric L. Petersen<br>Office: ENPO 110<br>Phone: (979) 845-1257<br>email: epetersen@tamu.edu<br>Office hours: W 09:00-11:00; TH 14:00-15:55; or by appointment |
| **Description:** | Gas dynamics, also referred to as compressible flow and/or high-speed aerodynamics, is a subject dealing with gas flows at high enough Mach number wherein the fluid can no longer be assumed incompressible. Such flows occur in many aerospace and mechanical engineering applications ranging from external aerodynamics to internal flows for applications such as propulsion and airframe designs for jets, rockets, missiles, and many other devices. Topics within high-speed aerodynamics include supersonic flows, shock waves, expansion waves, shock tubes, supersonic wind tunnels, gas flows with friction, and gas flows with heat transfer. |
| **Units:** | 3 |
| **Prerequisites:** | MEEN 344 – Fluid Mechanics<br>(or its equivalent) |
| **Lecture Times:** | T TH 09:35-10:50 **Room:** ENPH 205 |
| **Website:** | Vista |
| **Required Text:** | *Gas Dynamics*<br>by James E. A. John and Theo G. Keith<br>Pearson Prentice Hall, 2006 ISBN 0-13-120668-0 |
| **Grading:** | Midterm Exams (3) 70%<br>Final Exam 30% |

The course grade is based on three mid-term exams and a comprehensive final exam. The grading will be relative but, in general, the minimum scale will be based on A = 90-100%, B = 80-89%, C = 70-79%, etc. In other words, if you have an 82 average but the class average is 85, you will still get a B.

**Homework:**
Working homework problems is a necessity for learning and practicing the material. The student is responsible for keeping up with the homework assignments. The homework will not be turned in for a grade. The solutions will be given some time prior to the exam that uses the material on which the problems are based.

**Academic Honesty:**
Ethical behavior and academic honesty are expected and required of students and even more so of engineers and scientists. Evidence of cheating during an exam or other assignment for credit may result in failure of the entire course for the student(s) in question. The same goes for quizzes. Examples of cheating include, but are not limited to: 1) sharing answers or any portion of the problem solutions during an exam, either verbally or on paper; 2) use of cell phones or other electronic communication devices during an exam; 3) talking out loud during an exam, including talking in a language other than English; 4) looking on the paper(s) of the person sitting nearby who is also taking the exam; 5) passing notes or other messages during an exam.

***Aggie Honor Code:* "An Aggie does not lie, cheat, or steal, or tolerate those who do."**
Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning and to follow the philosophy and rules of the Honor System. Students will be required to state their commitment on examinations, research papers, and other academic work. Ignorance of the rules does not exclude any member of the Texas A&M University community from the requirements or the processes of the Honor System. For additional information please visit: www.tamu.edu/aggiehonor/

On all course work, assignments, and examinations at Texas A&M University, the following Honor Pledge shall be preprinted and signed by the student:

*"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work."*

**Americans with Disabilities Act (ADA) Policy Statement:**
The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact Disability Services, in Cain Hall, Room B118 or call 845-1637. For additional information visit http://disability.tamu.edu

**Absences:**
Work missed due to absences will only be excused for University-approved activities in accordance with TEXAS A&M UNIVERSITY STUDENT RULES (see http://student-rules.tamu.edu/rule7.htm). Specific arrangements for make-up work in such instances will be handled on a case-by-case basis. In accordance with recent changes to Rule 7, please be aware that in this class any "injury or illness that is too severe or contagious for the student to attend class" will require "a medical confirmation note from his or her medical provider" even if the absence is for less than 3 days (see 7.1.6.2 Injury or illness less than three days.).

**Course Outline:**

Table 1 presents the overall course schedule. The planned exam dates are subject to change upon prior notice of the instructor at least one week in advance of the exam date. The final exam will be during the university-designated time slot. The following topics will be covered, roughly in the sequence provided. The suggested homework will be provided on Vista and should be worked as we progress through the course. Solutions will be provided after a suitable amount of time has passed for people keeping pace with the course to practice the homework problems on their own.

Week 1: Introduction to compressible flow; ideal gases; conservation of mass; conservation of energy
Week 2: momentum equation; 2nd Law of Themodynamics; wave propagation in elastic media; Mach number; subsonic and supersonic flows
Week 3: isentropic flow of a perfect gas; varying area channels; stagnation properties; choked flow
Week 4: converging-diverging nozzles and diffusers; applications
Week 5: normal shock waves; governing equations for a stationary normal shock wave
Week 6: shock waves in a C-D nozzle; supersonic wind tunnels
Week 7: moving normal shock waves; reflected normal shock waves
Week 8: Shock tubes
Week 9: Oblique shock waves; oblique shock reflections
Week 10: gradual compressions and expansions; Prandtl-Meyer expansion fans; Prandtl-Meyer flow for a smooth compression
Week 11: supersonic oblique-shock diffuser; exit flow for supersonic nozzles; plug nozzle
Week 12: Supersonic airfoils
Week 13: Fanno flow line; relations of Fanno flow; 1-D flow problems with friction
Week 14: Rayleigh flow line; relations of Rayleigh; 1-D flow problems with heat transfer
Finals Week: Comprehensive final examination

**Table 1** Schedule for MEEN 472, Fall 2012

| Week | T | Th | Notes |
|---|---|---|---|
| 1 | 8/28 | 8/30 | |
| 2 | 9/4 | 9/6 | |
| 3 | 9/11 | 9/13 | |
| 4 | 9/18 | 9/20 | |
| 5 | 9/25 | 9/27 | |
| 6 | **10/2** | 10/4 | **Exam 1: 10/2** |
| 7 | 10/9 | 10/11 | |
| 8 | 10/16 | 10/18 | |
| 9 | 10/23 | 10/25 | |
| 10 | **10/30** | 11/1 | **Exam 2: 10/30** |
| 11 | 11/6 | 11/8 | |
| 12 | 11/13 | 11/15 | |
| 13 | 11/20 | - | Holiday: 11/22 |
| 14 | 11/27 | **11/29** | **Exam 3: 11/29** |
| 15 | 12/4* | - | * Redefined Th; **Final Exam: 12/7 12:30-14:30** |
| 16 | - | - | |

**Learning Outcomes:**

At the end of this course, students should be able to:

1. understand basic relations of fluid mechanics and thermodynamics (continuity, momentum, energy, $2^{nd}$ Law of Thermodynamics) from a control volume standpoint;
2. apply the ideal gas assumption;
3. use 1-D theory to understand basic wave propagation in gases and elastic media;
4. evaluate sound speeds of ideal gases and calculate Mach numbers;
5. categorize the various regimes defined by the Mach number (subsonic, supersonic, hypersonic, etc.);
6. utilize the concept of stagnation temperature and stagnation pressure for understanding and solving basic gas dynamics problems;
7. explain basic flow system behavior using T-s diagrams
8. evaluate the effect of area changes on 1-D compressible flow;
9. determine when a flow system is choked and what regions should be subsonic, sonic, or supersonic;
10. analyze the flow in nozzles, diffusers, and from pressurized vessels;
11. design (conceptually) basic supersonic wind tunnels;
12. analyze flow systems containing stationary normal shock waves;
13. analyze flow systems containing stationary oblique shock waves;
14. determine the location of a stationary shock wave in a converging-diverging nozzle;
15. calculate the conditions within ducted systems containing moving shock waves;
16. understand the fundamentals of shock tubes;
17. evaluate the pressure and Mach number changes through an expansion fan (Prandtl-Meyer flow);
18. apply oblique shock waves and expansion fans toward the design of supersonic airfoils;
19. apply oblique shock waves and expansion fans to supersonic nozzles and their exhaust streams
20. perform calculations on a compressible, 1-D internal flow system with friction
21. analyze compressible, 1-D internal flows with heat transfer
22. sketch Rayleigh and Fanno lines on a T-s diagram
23. Use look-up tables for solving basic compressible flow problems.
24. make small computer/EXCEL/MATHCAD programs for solving the basic relations of compressible flow using a computer and/or calculator without having to resort to look-up tables.