Sample Syllabus

ME 420: Compressible Flow I

Fall 2024 · Section 001

304 Hammond Building, MWF 11:15 am – 12:05 pm

Instructor Information

Instructor	Dr. David Williams	Email	dmw72@psu.edu
Office	136 Research East (by appointment only) E-Knowledge Commons (office hours)	Office Hours	M, W. 4:00-5:00 pm

Course Material Information

Course Description	Thermodynamic and dynamic principles applied to compressible fluid behavior under internal and external flow conditions.
Course Website	All course material assignments and grades will be distributed *via* Canvas. Graded homeworks and exams will (when possible) be returned in class.
Textbook	▪ Modern Compressible Flow with Historical Perspective. *3rd* or *4th Ed.* J. D. Anderson. [Required]
Recommended	▪ Compressible Fluid Dynamics. P. A. Thompson ▪ Elements of Gasdynamics, H. W. Liepmann and A. Roshko
Prerequisites	EMCH 212 (dynamics), Math 251(ODEs/PDEs), ME 201/300 (thermal sciences), MATH 230/231(vector calculus), ME 320 (fluid dynamics)

Course Objectives

Upon completion of this course, students should be able to:

1. Solve a range of compressible-flow problems often encountered in engineering practice, including isentropic flow, nozzle Mach number, and shock wave motion.
2. Apply physical thinking to problems of fluids and thermo-dynamics.
3. Integrate previous course material in fluids and thermo-dynamics, both of which factor equally in compressible flows.
4. Apply computer methods, such as Matlab, spreadsheet solutions, and Javascript calculators, to compressible-flow problems.
5. Identify and utilize the strong visual nature of flow patterns in engineering practice in the thermal sciences.
6. Demonstrate practical design skills such as supersonic nozzle and duct design

Attendance Policy and Emergencies

Students are responsible for all material covered during class, including assignments and quizzes. If the instructor is late, students should wait 15 minutes before leaving. In the event of a major campus emergency, course requirements, deadlines, and grading schemes are subject to changes that may be necessitated by a revised semester calendaror other circumstances beyond the instructor's control.

Students must pre-arrange absences for graded assignments and exams, or submit a documented excuse, e.g., a signed note from a doctor indicating that an assignment could not be completed due to illness, if such arrangements cannot be made.

Grading Policy

Final grades will be determined according to the following table.

20%	Homework
25%	Exam 1
25%	Exam 2
30%	Final Exam

The final grades may be determined using the following table.

--	$93 \leq \text{score} < 100 \Rightarrow$ A	$90 \leq \text{score} < 93 \Rightarrow$ A-
$87 \leq \text{score} < 90 \Rightarrow$ B+	$83 \leq \text{score} < 87 \Rightarrow$ B	$80 \leq \text{score} < 83 \Rightarrow$ B-
$77 \leq \text{score} < 80 \Rightarrow$ C+	$70 \leq \text{score} < 77 \Rightarrow$ C	--
--	$60 \leq \text{score} < 70 \Rightarrow$ D	--
--	$\text{score} < 60$ F	--

Notes on final grades:

1. All final score adjustments are in the discretion of the instructor.
2. Final grades may be normalized (i.e., divided) as needed by, for example, the largestfinal score in the class and multiplied by 100. The value of the normalization score may be smaller than the largest final score, based on the instructors' discretion and the overall course performance. For example, if the largest final score in the class isa 95, all other scores may be divided by a value ≤ 95. Depending on class performance, scores may also be curved. In all cases the order of students' scores will be preserved, i.e. students with higher raw scores will have higher normalized or curved scores.
3. Individual exam scores may be normalized and/or curved as needed. In all cases the order of students' scores will be preserved, i.e. students with higher raw scores will have higher normalized or curved scores.

Details on grade categories:

20% Homework

a) Homework assignments can include a combination of reading assignments,problem solving and computer work.

b) Homework assignments will be assigned on Fridays via *CANVAS*. These assignments will be **submitted remotely on *CANVAS the following Friday*.** Homework must be submitted **only** as a **single PDF file**. Any other type of file format, or submission of multiple files, will **not** be accepted, and it will automatically resultin a grade of **zero** for the assignment **without exception**. Upon uploading your single, legible PDF file, ensure you see a readable preview of it. If this is not the case, your upload has failed. Failed **uploads** cannot be resubmitted and will result in a grade of **zero** without exception. Late homework will **not** be accepted without an authorized excuse.

c) **Homework assignments are individual.** Collaboration on homework is limitedto general discussion of the problems and approaches. All students must independently complete their own written solution to each homework problem. Copying from another person's solutions, or from a previous course's posted solutions, or from **any place on the internet**, or from any other existing solutions is considered plagiarism and will result in disciplinary action according to Penn State's policies.

d) Every student'slowest homework score for the semester will be dropped.

25% Exam 1: Tuesday, Oct. 8, 08:00pm – 10:00pm, TBD

25% Exam 2: Tuesday, Nov. 12, 08:00pm – 10:00pm, TBD

30% Final: TBD

a) All exams will be closed notes and closed book, except for a student-generated cheat-sheet. In particular, **each student will be allowed to bring one 8.5x11 inch cheat-sheet** covered on both front and back with writing or typing. No materials other than thecheat-sheets are to be used during exams.

b) Graphing and scientific calculators are allowed on the exams.

c) A score of zero will be recorded for a missed exam without a documented, authorized excuse. For authorized absences, a student should work with his or her instructor to schedule a make-up exam.

d) Students are not allowed to collaborate, talk with one another, or use unauthorized materials on exams unless directed otherwise. Violation of thispolicy will result in a zero score for the exam.

Re-grade Policy:

Assignment **re-grades must be submitted within 1 week** of the date the graded document has been made available for return. After 1 week, re-grades will not be considered. Re-graderequests must include a written statement with justification for the re-grade. Tests and assignments are re-graded from scratch, which may result in a lower score than the original.

Academic Integrity Policy

Penn State University Policy 49-20 states:

> *"Academic integrity is the pursuit of scholarly activity in an open, honest and responsible manner. Academic integrity is a basic guiding principle for all academic activity at The Pennsylvania State University, and all members of the University community are expected to act in accordance with this principle."*

All students in this course are expected to act in accordance with this policy. **It is expected that any submitted works in this course are exclusively your own.** Students should report any academic dishonesty incidents for which they are aware of to the course instructor.

This course will maintain a zero-tolerance policy on academic dishonesty, cheating, and plagiarism. All academic dishonesty incidents will be reported to the University. Any student involved in any academic dishonesty incident will, at minimum, receive a zero for the assignment, and may receive a final grade of 'F' in the course.

Course materials and web pages including class notes and answer keys to old and current exams, homework, and quizzes are "considered to be 'derivative works' of the instructor's presentations and materials, and they are thus subject to the instructor's copyright in such presentations and materials." As such, they **cannot be sold or bartered (for example, on commercial web pages) without express written permission** of the instructor.

Academic dishonesty incidents include, but are not limited to:

- Cheating
  - For exams this includes: Copying other student's answers, bringing or using unauthorized information, providing assistance to another student's exam answers.
  - For homework this includes: Copying other student's solutions, copying solutions found online or from some other unauthorized source, allowing your solutions to be copied by any other student(s),
- Plagiarizing
- Providing homework and/or exam solution keys to anyone, and/or posting them online
- Possessing unauthorized homework and/or exam solution keys

Nondiscrimination Policy

Penn State is committed to fostering a diverse and inclusive environment for all students, faculty and staff. All students in this course are expected to treat other students, course instructors, and teaching assistants in a respectful and professional manner. Any acts of intolerance, discrimination, or harassment are expressly prohibited and should be reported to the University (http://equity.psu.edu/reportbias/).

Counseling and Psychological Services (CAPS)

Many students at Penn State face personal challenges or have psychological needs that may interfere with their academic progress, social development, or emotional wellbeing. The university offers a variety of confidential services to help you through difficult times, including individual and group counseling, crisis intervention, consultations, online chats, and mental health screenings. These services are provided by staff who welcome all

students and embrace a philosophy respectful of clients' cultural and religious backgrounds, and sensitive to differences in race, ability, gender identity and sexual orientation. Counseling and Psychological Services at University Park (CAPS) (http://studentaffairs.psu.edu/counseling/): 814-863-0395. Counseling and Psychological Services at Commonwealth Campuses (https://senate.psu.edu/faculty/counseling-services-at-commonwealth-campuses/). Penn State Crisis Line (24 hours/7 days/week): 877-229-6400. Crisis Text Line (24 hours/7 days/week): Text LIONS to 741741.

Disability Access

Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Student Disability Resources Web site provides contact information for every Penn State campus: http://equity.psu.edu/student-disability-resources/disability-coordinator. For further information, please visit the Student Disability Resources Web site: http://equity.psu.edu/student-disability-resources. In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: http://equity.psu.edu/student-disability-resources/applying-for-services. If the documentation supports your request for reasonable accommodations, your campus's disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. You must follow this process for every semester that you request accommodations.

Course Overview (subject to change)

CHAPTER 1: INTRODUCTION

- Flow Regimes, types of flows in ME 320 and ME 420
- Overview: density change, compressible flow, gas dynamics, and "thermo-fluid dynamics"

CHAPTER 2: CONSERVATION EQUATIONS

- The basic conservation equations and examples of their use
- 1-D flow approximation

CHAPTER 3: ONE-DIMENSIONAL FLOW

- Wave propagation, sound speed, and Mach number
- Alternate forms of the energy equation
- Normal shock waves.
  - what is a shock wave?
  - equations of motion, tabulated, and computed solutions
  - blast waves in the atmosphere
- Moving Normal shock waves. (Also see Sections 7.1 and 7.2)
- Mach Angle
- Pitot-Static Probes

EXAM 1. Tuesday, October 8th, 8:00-10:00 pm, TBD

CHAPTER 5: QUASI-ONE-DIMENSIONAL FLOW

- ISENTROPIC FLOW
  - equations of motion, tabulated, and computed solutions
  - static and stagnation properties
  - converging-diverging (Laval) nozzles
- NOZZLE FLOWS WITH SHOCK WAVE
- APPLICATIONS
  - Laval nozzle performance
  - Ducts with multiple contractions
  - supersonic wind tunnels, startup and run conditions
  - inlets for supersonic engines
  - other compressible-flow facilities

EXAM 2. Tuesday, November 12th, 8:00-10:00 pm, TBD

CHAPTER 3: ONE-DIMENSIONAL FLOW

- 3.9 Flow with friction (Fanno-line)
- pipe flow examples (e.g. natural gas pipeline problem)
- 3.8 Flow with heat addition (Rayleigh-line)

CHAPTER 4: TWO-DIMENSIONAL FLOW

- OBLIQUE SHOCK WAVES
  - eqns. of motion, tabulated, charted and computed solns.
  - wave reflections and crossings; shock polar diagram
  - conical oblique shocks
- PRANDTL-MEYER EXPANSION FANS
  - equations of motion, tabulated, and computed solutions
- APPLICATIONS
  - supersonic inlets and diffusers
  - Laval nozzle performance and supersonic free jets