

ME 420: Compressible Flow, Syllabus for Fall Semester 2022

John M. Cimbala, Penn State University. Latest update: 26 August 2022

- Lectures:** Mon., Wed., and Fri., 11:15-12:05 p.m., Room 101 Walker Building
- Text:** Recommended: *Modern Compressible Flow with Historical Perspective*, John D. Anderson, McGraw-Hill, Inc., New York, 2003. We use Edition 3, but older editions are acceptable.
- Prerequisite:** One undergraduate fluid mechanics course.
- Instructor:**
- John M. Cimbala, jmc6@psu.edu. Professor of Mechanical Engineering, 234 Reber Building, 814-863-2739 www.me.psu.edu/cimbala. ← Weekly schedule is posted on this website.
 - In-Person Office hours: **Thursday 2:00-3:00 pm**, 234 Reber Building
- TA/Grader:** **Kun-Hao Huang** – The TA will grade homework assignments; Dr. Cimbala will grade exams.

General Description and Course Outline:

This course is a technical elective for seniors and graduate students. Students should have as prerequisites at least one thermodynamics course and one fluid mechanics course, since compressible flow is a blend of both thermodynamics and fluid mechanics. We cover several unique concepts and applications of compressible flow, including: speed of sound and Mach number, isentropic 1-D flow in variable area ducts, converging nozzles, choking, converging-diverging nozzles, moving shocks, blast waves, shock tubes, Rayleigh flow (duct flow with heat transfer), Fanno flow (duct flow with friction), normal and oblique shocks, expansion fans, and other topics to be announced, time permitting.

Web Pages: There are two websites for this course: Penn State's Canvas site at <https://psu.instructure.com/> and the ME website at <http://www.me.psu.edu/cimbala/me420>. Students are expected to check both websites regularly for lecture notes and videos, homework assignments, homework solutions, quizzes, and other information. Hardcopies (handouts) of homework assignments will *not* be provided.

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 adiabatic isentropic flow in ducts and normal and oblique shock wave analysis.
2. Apply physical thinking and problem-solving techniques to practical problems using fluid mechanics and thermodynamics.
3. Integrate previous course material in fluids and thermodynamics into the study of compressible flow.
4. Apply computer programs (Matlab, Excel, EES, Javascript calculators, etc.) 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 design of supersonic nozzles and wind tunnels.
7. Demonstrate professionalism and respectful interaction with faculty and colleagues.

Lecture Schedule: A more detailed week-by-week breakdown is provided on the course website.

Week #	Topics to be Covered [Note: We will follow this schedule as closely as possible, <i>subject to change</i>]
1	Introduction and review: Review of fluid flow and thermodynamics; Differences between compressible and incompressible flow; Ideal gas, speed of sound, Mach number
2-4	1-D, adiabatic, isentropic duct flow of an ideal gas: Isentropic relations; One-D compressible adiabatic duct flow, critical properties; Converging nozzles, choking, converging-diverging nozzles, rocket nozzles
5-8	Normal shocks: Normal shocks in converging-diverging nozzles, property changes across shocks, Fanno Rayleigh, and Hogoniot curves, Pitot probes, moving normal shocks, explosions and blast waves
9	Shock tubes: piston-driven flow in pipes, expansion waves, reflecting shocks, $x-t$ diagrams
10-11	1-D duct flow with heat transfer: Rayleigh flow and equations, $T-s$ diagrams, choked Rayleigh flow
11-12	1-D duct flow with friction: Fanno flow, choked Fanno flow; Comparison/summary of 1-D flows
13-15	2-D flows: Oblique shocks, compression waves, reflecting oblique shocks, expansion waves, supersonic wings; tying it all together (practical applications of compressible flow); Review for final exam

Grading: All exams and homework assignments are *comprehensive*. Mark your calendars!

Homework	20%	One per week except during exam weeks – count highest 10 out of 11 – see website
Exam 1	25%	In class, Friday September 30
Exam 2	25%	In class, Friday November 4
Final Exam	30%	During Finals Week. Date, time, and location to be announced

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Grading Scale:

The following are minimum cutoffs for each grade:

- 90.00% = A
- 86.66% = A-
- 83.33% = B+
- 80.00% = B
- 76.66% = B-
- 73.33% = C+
- 70.00% = C
- 60.00% = D
- less than 60.00% = F

Grade Disputes: If a student feels that an exam or homework was graded unfairly, or if there is an error in the grading, it should be brought to the attention of the grader (TA: homework, Professor: quizzes and exams) within one week after the material is graded except under extenuating circumstances.

Cheating Policy: Cheating is not tolerated in this course. You should refer to the Academic Integrity website at <http://www.engr.psu.edu/faculty-staff/academic-integrity.aspx> which explains what behaviors are in violation of academic integrity, and the review process for such violations. On the next page is a summary of the policy. Specifically for this course:

- **First offense:** Zero score for the item in question, and infraction reported to the College.
- **Second offense:** Failure of the course, and infraction reported to the College.

Summary of Penn State's Academic Dishonesty Policy: The University defines academic integrity as the pursuit of scholarly activity in an open, honest and responsible manner. All students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts (refer to [Senate Policy 49-20](#)). Dishonesty of any kind will not be tolerated in this course. Dishonesty includes, but is not limited to, cheating, plagiarizing, fabricating information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of another person or work previously used without informing the instructor, or tampering with the academic work of other students. Students who are found to be dishonest will receive academic sanctions and will be reported to the University's Office of Student Conduct for possible further disciplinary sanctions (refer to [Senate Policy G-9](#)).

Definition and expectations: 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.

Accommodating Disabilities and Disability Access Statement:

Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Office for Disability Services (ODS) 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 [Office for Disability Services Web site](#) : <http://equity.psu.edu/ods> .

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](#): 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. See <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.

Counseling & Psychological Services (CAPS) Statement:

CAPS can help students resolve personal concerns that may interfere with their academic progress, social development, and satisfaction at Penn State. Some of the more common concerns include anxiety, depression, difficulties in relationships (friends, roommates, or family); sexual identity; lack of motivation or difficulty relaxing, concentrating or studying; eating disorders; sexual assault and sexual abuse recovery; and uncertainties about personal values and beliefs. You can contact CAPS by calling the Main CAPS number/Appointment Scheduling: 814-863-0395 (Please call between the hours of 8am and 5pm, Monday-Friday to schedule an appointment) or visit us at our office location, 5th Floor Student Health Center.

Sexual Assault and Relationship Violence Hotline:

A hotline has been established for victims and observers of sexual assault and relationship violence. Trained counselors on the hotline will help students access appropriate resources. Penn State students from any campus can call 1 (800) 560-1637 to access the 24 hour a day, seven day a week hotline.

Library Resources:

Many of Penn State's library resources can be utilized from a distance. Through the University Libraries website, you can

- access magazine, journal, and newspaper articles online using library databases;

- borrow materials and have them delivered to your doorstep...or even your desktop;
- get research help via e-mail, chat, or phone using the [Ask a Librarian service \(Links to an external site.\)Links to an external site.](#); and much more.

You must have an active Penn State Access Account to take full advantage of the University Libraries' resources and services. Once you have a Penn State account, you will automatically be registered with the library within 24–48 hours. If you would like to check that your registration has been completed, visit the [Libraries home page \(Links to an external site.\)Links to an external site.](#), click on **Library Accounts**, and then click on **My Library Account**.

Academic Integrity:

Academic integrity—scholarship free of fraud and deception—is an important educational objective of Penn State. Academic dishonesty can lead to a failing grade or referral to the [Office of Student Conduct \(Links to an external site.\)Links to an external site.](#) Academic dishonesty includes but is not limited to

- cheating,
- plagiarism,
- fabrication of information or citations,
- facilitating acts of academic dishonesty by others,
- unauthorized prior possession of examinations,
- submitting the work of another person or work previously used without informing the instructor and securing written approval, and
- tampering with the academic work of other students.

The University defines academic integrity as the pursuit of scholarly activity in an open, honest and responsible manner. All students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts (refer to Senate Policy 49-20). Dishonesty of any kind will not be tolerated in this course. Dishonesty includes, but is not limited to, cheating, plagiarizing, fabricating information or citations, facilitating acts of academic dishonesty by others, having unauthorized possession of examinations, submitting work of another person or work previously used without informing the instructor, or tampering with the academic work of other students. Students who are found to be dishonest will receive academic sanctions and will be reported to the University's Office of Student Conduct for possible further disciplinary sanctions (refer to Senate Policy G-9).

How Academic Integrity Violations Are Handled:

In cases where academic integrity is questioned, the [Policy on Academic Integrity \(Links to an external site.\)Links to an external site.](#) indicates that procedure requires an instructor to notify a student of suspected dishonesty before filing a charge and recommended sanction with the college. Procedures allow a student to accept or contest a charge. If a student chooses to contest a charge, the case will then be managed by the respective college or campus Academic Integrity Committee. If a disciplinary sanction also is recommended, the case will be referred to the [Office of Student Conduct \(Links to an external site.\)Links to an external site.](#) All Penn State colleges abide by this Penn State policy, but review procedures may vary by college when academic dishonesty is suspected. Information about Penn State's academic integrity policy and college review procedures is included in the information that students receive upon enrolling in a course. To obtain that information in advance of enrolling in a course, please contact us by going to the [Contacts & Help page \(Links to an external site.\)Links to an external site.](#)

Additionally, World Campus students are expected to act with civility and personal integrity; respect other students' dignity, rights, and property; and help create and maintain an environment in which all can succeed through the fruits of their own efforts. An environment of academic integrity is requisite to respect for oneself and others, as well as a civil community.

For More Information on Academic Integrity at Penn State:

Please see the [Academic Integrity Chart \(Links to an external site.\)Links to an external site.](#) for specific college contact information or visit one of the following sites:

- Penn State Senate [Policy on Academic Integrity \(Links to an external site.\)Links to an external site.](#)
- [iStudy for Success! \(Links to an external site.\)Links to an external site.](#) (education module about plagiarism, copyright, and academic integrity)
- [Turnitin \(Links to an external site.\)Links to an external site.](#) (a web-based plagiarism detection and prevention system)