

MAE 336 – Compressible Aerodynamics
Mechanical and Aerospace Engineering Department – West Virginia University
Spring 2021, MWF 11:00 – 11:50 AM, 1021 SAS

Instructor: Dr. Christopher Griffin, Teaching Assistant Professor, MAE Dept.
Office Hours: Mondays 2 – 3 PM, Thursdays 10 – 11 AM, or by appointment (open door policy)
Office Hours Zoom Link:
Contact Info: Office – 939 ESB, Email – cgriffin@mail.wvu.edu

Course Description

MAE 336 covers the fundamental concepts of compressible aerodynamic theory; including an introduction to hypersonic flow. Topics include analysis and design of compressible, inviscid flows, isentropic flow, shock waves, Prandtl-Meyer expansions, and supersonic nozzles and diffusers. The course will also identify aspects of airfoils in compressible flows, including small perturbation theory. Students will be expected to use MS Word, MS Excel, and MATLAB in this course. This course is primarily an introduction to theoretical aspects of compressible aerodynamics, and as such you can expect to see and use mathematics (although not as much, or as high a level as in MAE 335).

Course Prerequisites: MAE 320 and (MAE 215 or MAE 331)

Course Textbook: Fundamentals of Aerodynamics, 6th Edition, J. D. Anderson, Jr., McGraw-Hill, 2017

General Course Outline

- Ch. 7 (5hrs) Compressible Flow Preliminaries
- Ch. 8 (6hrs) Normal Shocks
- Ch. 9 (6hrs) Oblique Shocks & Prandtl-Meyer Expansions
- Ch. 10 (9hrs) Supersonic Nozzles, Diffusers, and Wind Tunnels
- Ch. 11 (5hrs) Subsonic Compressible Airfoil Linear Theory
- Ch. 12 (6hrs) Supersonic Compressible Airfoil Linear Theory
- Ch. 13 (3hrs) Introduction to Numerical Techniques for Nonlinear Supersonic Flow
- Ch. 14 (3hrs) Hypersonic Flow

Grading

The final grade in the course will be assigned on the following basis:

Homework/Quizzes	10%
Project	10%
Exam 1	25%
Exam 2	25%
Final Exam	30%

Final course grade will be submitted as: A (≥89.5%), B (≥79.5%), C (≥69.5%), D (≥59.5%), F (<59.5%)

NOTE: A final course score of 59.4% and below is a letter grade of “F”, whether you are graduating or not, have a job lined up or not. No exceptions.

Key Course Objectives

It is the intent of this course that:

1. Students will be exposed to and discuss the fundamental aspects of compressible aerodynamics.
2. Students will be able to utilize knowledge from (1.) and apply effective problem-solving skills to evaluate and/or design basic aerodynamic-related configurations.

- Students will have discussion related to contemporary and global issues in aerodynamics.

Key Course Learning Outcomes

Through satisfactory completion of homework, quiz and exam problems, as well as through classroom discussion, successful students will be able to:	ABET Outcome*
1. Apply basic fluid flow conservation principles and mathematics to solve engineering problems related to compressible aerodynamics;	1
2. Analyze and design supersonic airfoils and nozzles;	1

*Prescribed ABET Course Outcomes for MAE 336

ABET Outcome 1: Upon graduation, all Bachelor of Science Students in mechanical or aerospace engineering will have an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

Spring 2021 General Academic Calendar Key Dates

JAN 18	MLK, Jr. Recess (No Classes)	MAR 12	Mid-Check Grades Due
JAN 19	First Day of Classes	APR 2	Spring Holiday (No Classes)
JAN 25	Last day to modify courses	APR 16	Last Day to Drop/Withdraw
Feb 11	No Classes	APR 30	Last Day of Classes
MAR 2-3	No Classes	May 3	Prep Day
		May 7, 11am	Final Exam

Engagement Policy

There is no doubt we are in very unusual times. I appreciate all of you continuing your education despite the obstacles that we all are facing. I hope none of us gets sick, I also hope no one close to us gets sick, but I am prepared to work with anyone that may need to miss lecture or assignments due to COVID-19 or any other serious issue. I encourage you to reach out to me as soon as any issue arises so we can work out a plan to keep you up to speed and allow you to finish the course.

To this end, I will make use of TopHat to encourage engagement and take attendance, as well as to provide a space for you to collaborate with each other. Attendance will be taken at each class, as well as seats will be assigned according to WVU Policy. The join code for TopHat is 792247.

Additional Exam Policy:

The following guidelines are imposed during every exam in MAE 336:

- Exams will be take-home type exams, with a due date and time. The exams will need to be scanned and uploaded via eCampus. Late exams will not be accepted as described in the previous section.
- Exams will be open notes and text, but there is to be no communication amongst students during the exam.

Assignment Policy

All assignments are due at the beginning of the assigned period, including electronically submitted material. Make-up exams and late assignments will **NOT** be accepted without **prior approval granted at least 2 days before the due date** from the instructor, consistent with WVU policies. Neat work is expected on all material submitted for grading (i.e. have to be able to read it to grade it). **Multiple sheets must be stapled, problems**

in the order assigned, and name and mailbox number must be on top of first page. You may use engineering problem paper or standard notebook paper, but NOT scratch paper or paper torn from a spiral notebook and write on only one side of each page. All assignments turned in for grading must be your own individual work; copying homework is unethical.

Academic Integrity

The integrity of the classes offered by any academic institution solidifies the foundation of its mission and cannot be sacrificed to expediency, ignorance, or blatant fraud. Therefore, instructors will enforce rigorous standards of academic integrity in all aspects and assignments of their courses. For the detailed policy of West Virginia University regarding the definitions of acts considered to fall under academic dishonesty and possible ensuing sanctions, please see the West Virginia University [Academic Standards Policy](http://catalog.wvu.edu/undergraduate/coursecredittermsclassification) (<http://catalog.wvu.edu/undergraduate/coursecredittermsclassification>). Should you have any questions about possibly improper research citations or references, or any other activity that may be interpreted as an attempt at academic dishonesty, please see your instructor before the assignment is due to discuss the matter.

Policy of Zero Tolerance in Academic Dishonesty. It is a MAE Departmental Policy, that cheating of any kind or form in exams, quizzes, projects or assignments will result in formal disciplinary action that may include unforgivable F (UF), suspension or dismissal from the Program.

Adverse Weather Statement

In the event of inclement or threatening weather, everyone should use his or her best judgment regarding travel to and from campus. Safety should be the main concern. If you cannot get to class because of adverse weather conditions, you should contact your instructor as soon as possible. Similarly, if your instructor(s) are unable to reach the class location, they will notify you of any cancellation or change as soon as possible, using WVU MIX email to prevent students from embarking on any unnecessary travel. If you cannot get to class because of weather conditions, instructors will make allowances relative to required attendance policies, as well as any scheduled tests, quizzes, or other assessments.

Appropriate Use of Technology Statement

Use of technology in the classroom should always be directly related to class activities and/or course learning outcomes. Inappropriate technology use can be an impediment to learning and a distraction to all members of the class. As such, inappropriate use of technology in the classroom may be considered a disruption of the class and constitute a violation of the [WVU Student Conduct Code](#) and could potentially result in a referral to the Office of Student Conduct. Use of technology in the classroom when specifically prohibited by the instructor may also constitute a violation of [WVU's Academic Integrity](#) policy.

Campus Safety Statement

The WVU Police are committed to creating and maintaining a safe learning environment for all students, faculty, and staff. Part of this mission includes educating the campus community on how to respond to potential campus threats, such as the threat of an active shooter on campus or other suspicious behaviors. Fortunately, WVU Police offer training - both online and in-person - on how to handle a variety of campus safety scenarios. All students are encouraged to visit the [WVU Police webpage](#), in particular the content under the [Active Shooter](#) training program. Students are also encouraged to report any suspicious behaviors on campus using the [Report a Threat](#) portion of the webpage. Additional materials on campus safety prepared by WVU Police, including special safety tips and training, will also be provided on our eCampus page. [adopted 10-2-17]

Notice of Class Recording Policy

Meetings of a course at West Virginia University (WVU), whether online or in-person, may be recorded. Recordings are not guaranteed, and are intended to supplement the planned class session. Recordings will be made available to class participants, which may include students, assistants, guest lecturers, and co-facilitators. Recordings may be shared by the instructor or institution in accordance with WVU Rules and policies. The Recordings are owned by and contain intellectual property of WVU. The Recordings may not be shared, copied, reproduced, redistributed, transferred, or disseminated in any form or by any means without the prior written consent of authorized officials of WVU.

COVID-19 Statement

WVU is committed to maintaining a safe learning environment for all students, faculty, and staff. Should campus operations change because of health concerns related to the COVID-19 pandemic, it is possible that this course will move to a fully online delivery format. If that occurs, students will be advised of technical and/or equipment requirements, including remote proctoring software.

In a face-to-face environment, our commitment to safety requires students, staff, and instructors to observe the social distancing and personal protective equipment (PPE) guidelines set by the University at all times. While in class, students will sit in assigned seats when applicable and wear the required PPE. Should a student forget to bring the required PPE, PPE will be available in the building for students to acquire. Students who fail to comply will be dismissed from the classroom for the class period and may be referred to the Office of Student Conduct for further sanctions.

If a student becomes sick or is required to quarantine during the semester, they should notify the instructor. The student should work with the instructor to develop a plan to receive the necessary course content, activities, and assessments to complete the course learning outcomes.

Sale of Course Material Statement

All course materials, including lectures, class notes, quizzes, exams, handouts, presentations, and other course materials provided to students for their courses are protected intellectual property. As such, the unauthorized purchase or sale of these materials may result in disciplinary sanctions under the [Student Conduct Code](https://studentconduct.wvu.edu/campus-student-code). (https://studentconduct.wvu.edu/campus-student-code) [adopted 5-11-2015]

Inclusivity Statement

The West Virginia University community is committed to creating and fostering a positive learning and working environment based on open communication, mutual respect, and inclusion.

If you are a person with a disability and anticipate needing any type of accommodation in order to participate in your classes, please advise your instructors and make appropriate arrangements with [the Office of Accessibility Services](https://accessibilityservices.wvu.edu/). (https://accessibilityservices.wvu.edu/)

More information is available at the [Division of Diversity, Equity, and Inclusion](https://diversity.wvu.edu/) (https://diversity.wvu.edu/) as well.

Sexual Misconduct Statement

West Virginia University does not tolerate sexual misconduct, including harassment, stalking, sexual assault, sexual exploitation, or relationship violence [[BOG Rule 1.6](https://policies.wvu.edu/finalized-bog-rules/bog-governance-rule-1-6-rule)] (https://policies.wvu.edu/finalized-bog-rules/bog-governance-rule-1-6-rule). It is important for you to know that there are resources available if you or someone you know needs assistance. You may speak to a member of university administration, faculty, or

staff; keep in mind that they have an obligation to report the incident to the [Title IX Coordinator](#).
(<https://titleix.wvu.edu/staff>)

If you want to speak to someone who is permitted to keep your disclosure confidential, please seek assistance from the [Carruth Center](#), **304-293-9355** or **304-293-4431** (24-hour hotline), and locally within the community at the [Rape and Domestic Violence Information Center](#) (RDVIC), **304- 292-5100** or **304-292-4431** (24-hour hotline).

For more information, please consult [WVU's Title IX Office](#) (<https://titleix.wvu.edu/confidential-resources>).

Disclaimer

The instructor reserves the right to deviate from the syllabus when a change is in the best interests of the class, as determined by the instructor.

Planned Lecture Schedule

Lecture	Date	Topic	Text Section
1	1/20	Introduction; Thermodynamics Review	7.1, 7.2
2	1/22	Thermodynamics Examples; Compressibility	7.2, 7.3
3	1/25	Conservation Equations	7.4
4	1/27	Total (Stagnation) Conditions	7.5
5	1/29	Example Problems	7.5
6	2/1	Normal Shock Equations, Speed of Sound	8.1 – 8.3
7	2/3	Example Problems, Energy Equation	8.3, 8.4
8	2/5	M^* , More Examples, When is flow Compressible?	8.4, 8.5
9	2/8	Normal Shock Properties	8.6
10	2/10	Example Problems, Pitot Tube when supersonic	8.6, 8.7
11	2/12	Introduction to Oblique Shocks and Expansion Fan	9.1
12	2/15	Oblique Shock Relations	9.2
13	2/17	Oblique Shock Examples	9.2, 9.3
14	2/19	Shock Reflections; Blunt Body Shock	9.4, 9.5
15	2/22	Prandtl-Meyer Expansion Waves	9.6
16	2/24	Exam 1	Ch 7 – Ch 9.3
17	2/26	P-M Waves Examples	9.6
18	3/1	Shock-Expansion Theory and Airfoils	9.7
19	3/5	Example Problems; X-15; Viscous Flow	9.7, 9.9, 9.10
20	3/8	Introduction to Ch. 10	10.1, 10.2
21	3/10	Nozzle Flows	10.3
22	3/12	Nozzle Flows; Nozzle Examples	10.3
23	3/15	Nozzle Examples; Diffusers and Wind Tunnels	10.3, 10.4
24	3/17	Diffusers; Supersonic Wind Tunnels	10.4, 10.5
25	3/19	Subsonic Compressible Flow – Velocity Potential	11.1, 11.2
26	3/22	Linearized Velocity Potential Equation	11.3
27	3/24	Prandtl-Glauert Compressibility Correction	11.4
28	3/26	Improved Compressibility Corrections; Critical Mach #	11.5, 11.6
29	3/29	Drag-Divergence Mach; Area Rule	11.7, 11.8
30	3/31	Supercritical Airfoils; CFD	11.9 – 11.11
31	4/5	Exam 2	Ch 9.4 – Ch 11.3
32	4/7	High Speed Airfoils, Swept Wing, BWB	11.11 – 11.14
33	4/9	Linearized Supersonic Pressure Coefficient	12.1, 12.2
34	4/12	Linearized Supersonic Pressure Coefficient	12.2
35	4/14	Supersonic Airfoils, Examples	12.3
36	4/16	Viscous Flow: Supersonic Airfoil Drag	12.4
37	4/19	General Airfoils: Supersonic Airfoil Drag	19.2, 18.4
38	4/21	Supersonic Airfoil Drag	19.2, 18.4
39	4/23	Method of Characteristics	13.2
40	4/26	Nozzle Design	13.3
41	4/28	Introduction to Hypersonics; Newtonian Theory	14.1 – 14.3
42	4/30	Newtonian Theory: Flat Plate at AoA	14.4
	572, 11am	Final Exam	Ch 7 – Ch 14

Note: Dates and topics covered are subject to change, but I will do my best to adhere to this schedule