**MAE 336 – Compressible Aerodynamics**
**Mechanical and Aerospace Engineering Department – West Virginia University**
**Spring 2019, MWF 11:00 – 11:50 AM, G-39 ESB**

**Instructor:** Dr. Christopher Griffin, Teaching Assistant Professor, MAE Dept.
Office Hours: Mondays 2 – 3 PM, Tuesdays 10 – 11 AM, or by appointment (open door policy)
Contact Info: Office – 939 ESB, Phone – 304.293.3386, 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.
3. 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 2019 General Academic Calendar Key Dates**

| | | | |
|---|---|---|---|
| JAN 7 | First Day of Classes | MAR 22 | Last Day to Drop a Class |
| JAN 11 | Last Day to Modify Classes | APR 19 | Spring Holiday (No Classes) |
| JAN 21 | MLK, Jr. Recess (No Classes) | APR 25 | Last Day to Withdraw |
| MAR 1 | Mid-Semester Grades Due | APR 26 | Last Day of Classes |
| MAR 9 – MAR 17 | Spring Recess (No Classes) | May 2 , 11am | Final Exam |

**Attendance Policy**

Although attendance will not be used as a grading criterion, I believe attendance is required to successfully complete this course. I will take attendance every lecture period using CBORD Mobile ID (see the following link, https://wvu.teamdynamix.com/TDClient/KB/ArticleDet?ID=35439#!) for my own records. Again, no percentage of your grade will be attributed to attendance.

**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/coursecreditstermsclassification). 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.

**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/)

More information is available at the Division of Diversity, Equity, and Inclusion (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). 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 | 1/7 | Introduction; Thermodynamics Review | 7.1, 7.2 |
| 2 | 1/9 | Thermodynamics Examples; Compressibility | 7.2, 7.3 |
| 3 | 1/11 | Conservation Equations | 7.4 |
| 4 | 1/14 | Total (Stagnation) Conditions | 7.5 |
| 5 | 1/16 | Example Problems | 7.5 |
| 6 | 1/18 | Normal Shock Equations, Speed of Sound | 8.1 – 8.3 |
| 7 | 1/23 | Example Problems, Energy Equation | 8.3, 8.4 |
| 8 | 1/25 | $M^*$, More Examples, When is flow Compressible? | 8.4, 8.5 |
| 9 | 1/28 | Normal Shock Properties | 8.6 |
| 10 | 1/30 | Example Problems, Pitot Tube when supersonic | 8.6, 8.7 |
| 11 | 2/1 | Introduction to Oblique Shocks and Expansion Fan | 9.1 |
| 12 | 2/4 | Oblique Shock Relations | 9.2 |
| 13 | 2/6 | Oblique Shock Examples | 9.2, 9.3 |
| 14 | 2/8 | Oblique Shock Examples | 9.3 |
| 15 | 2/11 | Shock Reflections; Blunt Body Shock | 9.4, 9.5 |
| 16 | 2/13 | Prandtl-Meyer Expansion Waves | 9.6 |
| **17** | **2/15** | **Exam 1** | **Ch 7 – Ch 9.3** |
| 18 | 2/18 | P-M Waves Examples | 9.6 |
| 19 | 2/20 | Shock-Expansion Theory and Airfoils | 9.7 |
| 20 | 2/22 | Example Problems; X-15; Viscous Flow | 9.7, 9.9, 9.10 |
| 21 | 2/25 | Introduction to Ch. 10 | 10.1, 10.2 |
| 22 | 2/27 | Nozzle Flows | 10.3 |
| 23 | 3/1 | Nozzle Flows; Nozzle Examples | 10.3 |
| 24 | 3/4 | Nozzle Examples; Diffusers and Wind Tunnels | 10.3, 10.4 |
| 25 | 3/6 | Diffusers; Supersonic Wind Tunnels | 10.4, 10.5 |
| 26 | 3/8 | Subsonic Compressible Flow – Velocity Potential | 11.1, 11.2 |
| 27 | 3/18 | Linearized Velocity Potential Equation | 11.3 |
| 28 | 3/20 | Prandtl-Glauert Compressibility Correction | 11.4 |
| 29 | 3/22 | Improved Compressibility Corrections; Critical Mach # | 11.5, 11.6 |
| 30 | 3/25 | Drag-Divergence Mach; Area Rule | 11.7, 11.8 |
| 31 | 3/27 | Supercritical Airfoils; CFD | 11.9 – 11.11 |
| **32** | **3/29** | **Exam 2** | **Ch 9.4 – Ch 11.3** |
| 33 | 4/1 | High Speed Airfoils, Swept Wing, BWB | 11.11 – 11.14 |
| 34 | 4/3 | Linearized Supersonic Pressure Coefficient | 12.1, 12.2 |
| 35 | 4/5 | Linearized Supersonic Pressure Coefficient | 12.2 |
| 36 | 4/8 | Supersonic Airfoils, Examples | 12.3 |
| 37 | 4/10 | Viscous Flow: Supersonic Airfoil Drag | 12.4 |
| 38 | 4/12 | General Airfoils: Supersonic Airfoil Drag | 19.2, 18.4 |
| 39 | 4/15 | Supersonic Airfoil Drag | 19.2, 18.4 |
| 40 | 4/17 | Method of Characteristics | 13.2 |
| 41 | 4/22 | Nozzle Design | 13.3 |
| 42 | 4/24 | Introduction to Hypersonics; Newtonian Theory | 14.1 – 14.3 |
| 43 | 4/26 | Newtonian Theory: Flat Plate at AoA | 14.4 |
| | **5/2, 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**