

MAE 433 – Computational Fluid Dynamics
Mechanical, Materials, and Aerospace Engineering Department
West Virginia University
Spring 2024

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| Lecture Info | Section 001 MWF, 12:00 – 12:50 AM, G11 ESB |
| Instructor Info | Dr. Christopher Griffin, Teaching Associate Professor Office Hours: M, 2:00 – 3:00 PM; Th, 10:00 AM – 11:00 AM; open door policy Contact Info: 939 ESB, 304.293.3386, cgriffin@mail.wvu.edu |
| Prerequisites | Grade of D- or better in MAE 316 and MAE 331 or MAE 335. Some experience with a common programming language (Fortran, Matlab, C, Python) |
| Required Textbook | Tu, Jiyuan, Guan Heng Yeoh, and Chaoqun Liu. <i>Computational fluid dynamics: a practical approach</i> . Butterworth-Heinemann, 2018. |
| Recommended Textbook | Anderson, John D. <i>Computational Fluid Dynamics: The Basics with Applications</i> . McGraw-Hill, 1995. |

Course Description

MAE 434 provides an introduction to modern computational fluid dynamics. Topics include the development and implementation of finite-difference and finite-volume schemes for numerical flow solutions. Grid generation techniques are also covered. Explicit, implicit, and iterative solution techniques are explored and discussed. There is also an emphasis on application using commercial solvers. Finally, best practices in validation and verification of solutions are investigated.

Grading Scheme

| Assignment | Weight |
|------------------|--------|
| Homework/Quiz | 15% |
| Semester Project | 15% |
| Exam 1 | 20% |
| Exam 2 | 20% |
| Final Exam | 30% |

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

Option to Submit Mid-term Exam Corrections

It is my belief that reviewing your work, particularly exams, will benefit your overall performance in this course. Therefore, all students have the option to submit corrections to their mid-term exams **within one week** of them being graded and returned. The original exam must be submitted with corrections completed on a separate piece of paper and stapled on top of the original exam. The following is the schedule for percentage points added to the original exam score.

| Original Exam Score | Potential Missed Points Returned |
|---------------------|----------------------------------|
| 90% – 100% | 60% |
| 80% – 89% | 50% |
| 70% – 79% | 40% |
| < 70% | 30% |

Course Objectives

The objectives of this course are to introduce the fundamentals of computational fluid dynamics, develop the skills to transform the governing equations for numerical analysis, and apply this knowledge to the solutions of various fluid flow applications. A variety of solution methods will be discussed and practiced and hands-on experience with the commercial solver Fluent will be obtained.

Course Learning Outcomes

This course addresses ABET Student Outcomes 1, 4, and 7.

Definitions and descriptions are available at the MMAE Program Accreditation and Assessment webpage,

<https://mmae.statler.wvu.edu/home/aerospace-engineering-program-accreditation-and-assessment>

Through satisfactory completion of homework, quiz and exam problems, the semester project, as well as through classroom discussion, successful students will demonstrate the ability to

- Apply the governing equations of fluid dynamics to specific flow phenomena (ABET Student Outcome 1).
- Implement fundamental discretization techniques, grid generation, and CFD techniques in software to solve fluid dynamics and heat transfer problems (ABET Student Outcome 1).
- Transform the governing equations of fluid dynamics for use in numerical analysis (ABET Student Outcome 1).
- Identify and explain strengths and weaknesses of current CFD practices (ABET Student Outcome 4).
- Conduct validation and uncertainty quantification of CFD results (ABET Student Outcome 4).

- Operate a commercial CFD software package and classify the solution techniques (ABET Outcome 7).

Prescribed ABET Student Outcomes for MAE 434

- 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.
- ABET Outcome 4 Upon graduation, all Bachelor of Science Students in mechanical or aerospace engineering will have an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
- ABET Outcome 7 Upon graduation, all Bachelor of Science Students in mechanical or aerospace engineering will have an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Assignment Policy

Make-up exams, quizzes, late homework, or late reports 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). **All written assignments will be scanned and submitted via eCampus.**

Engagement Policy

Regular attendance is expected and necessary for students who wish to master the topics covered in this course. To promote attendance, four bonus percentage points are available to be added to your final course average. The breakdown of the awarded points are as follows.

| Days Missed | Points Awarded |
|-------------|----------------|
| 0 | 4 |
| 2 (5%) | 3 |
| 4 (10%) | 2 |
| 6 (15%) | 1 |
| > 6 | 0 |

Excused and sanctioned absences, as outlined in the WVU Attendance Policy, are not counted against your attendance record. Unannounced in-class exercises may also be administered for credit. Only excused, sanctioned, or previously discussed absences will be permitted to make-up the exercise.

Spring 2024 General Academic Calendar Key Dates

| | | | |
|-----------|----------------------------|-------------|-----------------------------|
| JAN 13 | First Day of Classes | APR 18 | Spring Holiday (No Classes) |
| JAN 17 | Last Day to Modify Courses | APR 21 | Last Day to Drop/Withdraw |
| JAN 20 | MLK, Jr. Day (No Classes) | MAY 02 | Last Day of Classes |
| FEB 28 | Mid-Check Grades Due | MAY 07 2 PM | Final Exam* |
| MAR 15-23 | Spring Recess (No Classes) | | |

***If a student has more than three final examinations in one day, the student may make arrangements to reschedule the last examination of the day during the make-up examination period.**

Teaching Philosophy

As the instructor, I will do everything possible to help you learn and understand the material, but you must do your part. The student is ultimately responsible for learning the material. It is not a trivial matter to earn an “A” in my course, but in the same respect, it is also difficult to receive an “F”. It is my opinion that discussion in the classroom helps reinforce concepts. Please participate in our discussions and never hesitate to ask a question.

If you have a question on material, homework, how I graded, or life in general, please come and see me as soon as possible. The earlier we can address a deficiency, the better. I am always open to meeting to discuss any questions and concerns.

Finally, I cannot stress enough the importance of doing all assigned work yourself. This includes reading, homework, projects, and self-study. I believe this approach is the only way to learn to address the following questions when solving a problem: a) what is the problem asking, b) what relevant theory do I need to apply, c) what is a representative system drawing for this problem, d) what assumptions and simplifications can I make, e) what local, initial or boundary condition information do I need, and f) what are the steps to solve this problem? **In other words, do not confuse copying solutions with asking your peers for help.**

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 agreed upon methods 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, <http://accessibilityservices.wvu.edu/>.

More information is available at the Division of Diversity, Equity, and Inclusion website as well, <http://diversity.wvu.edu/>.

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>.

Mental Health Statement

Mental health concerns or stressful events can adversely affect your academic performance and social relationships. WVU offers services to assist you with addressing these and other concerns that you may be experiencing. You can learn more about the broad range of confidential mental health services available on campus at the Carruth Center for Counseling and Psychological Services (CCCPS) website: <https://carruth.wvu.edu/>.

- If you are in need of crisis services, call the CCCPS main number 24/7: (304) 293-4431.

Crisis services are also available through text: Text WVU to 741741 for support 24/7 from a trained Crisis Counselor.

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, <http://titleix.wvu.edu/what-is-title-ix/who-is-the-title-ix-coordinator>.

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 students at WVU-Beckley, contact the Women's Resource Center at 304-255-1585 (toll free at 1-888-825-7836) or REACH at 304-340-3676. For students at WVU-Keyser, contact the WVU-Keyser Psychological Counseling Services Office at 304-788-6976, and locally in Keyser, the Family Crisis Center, 304-788-6061 or 1-800-698-1240 (24-hour hotline).

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

Academic Integrity Statement

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.

Statler College Policy of Academic Integrity

| Case | Violation | Penalty |
|------|---|---|
| 1 | Cheating or plagiarism on minor course element (e.g., quiz, weekly lab report, homework as specified in the syllabus) | Report of academic dishonesty Grade of zero on the entire minor course element Possible one-letter reduction in final grade |
| 2 | Cheating or plagiarism on a major course element (e.g., exam, project) | Report of academic dishonesty Grade of zero on the entire major course element Possible one-letter reduction in final grade Possible UF [†] recommendation Possible exclusion from further participation in class |
| 3 | Collusion on major course element | Report of academic dishonesty Exclusion from further participation in class Failure in the course Recommendation for UF [†] |
| 4 | Other (document alteration, tampering with records, etc.) | Report of academic dishonesty Grade of zero on the entire major course element Possible additional one-letter reduction in final grade Possible failure in the course Possible exclusion from further participation in class Possible recommendation for UF [†] |

[†] UF – Unforgivable F Grade; cannot be replaced under D-F repeat policy.

Additional notes:

- Dismissal from Statler College is permanent for Academic Integrity violations. Student conduct violations can be considered in dismissal.
- Seperable sanctions (e.g., dismissal from Statler College, suspension, or expulsion from WVU) will be recommended for aggravated or second AI offenses.
- Warning letters may be issued from the Statler College or the WVU Office of Student Conduct.
- Sanctions will be assessed at the instructor and at the college/university levels. Additional sanctions may be assigned at the level of the instructor, college, and/or university.
- FORBIDDEN on Exams and Quizzes: The use of programmable calculators or smart devices (including smart-phones, smart watches, tablets, cameras, wearable devices, etc.) is prohibited unless specifically indicated by the instructor.

Course Topics

Introduction to CFD, 2 hours

- What is CFD?
- CFD Process Outline

Review of the Governing Equations, 4 hours

- Conservation of Mass
- Conservation of Momentum
- Conservation of Energy
- The General Transport Equation
- Non-dimensional form

Partial Differential Equations, 5 hours

- Order and Linearity
- PDE Classification
- PDE Discretization using Finite Differences
- Solving a Linear System of Equations

The Finite Volume Method, 6 hours

- Introduction
- Diffusion
- Convection-Diffusion

Unsteady Considerations, 3 hours

- Explicit and Implicit Techniques
- Stability

Mesh Development, 8 hours

- Structured and Unstructured meshes
- Mesh quality measures
- Meshing in ICEM CFD
- Meshing in ANSYS Meshing
- Meshing in Fluent Meshing

Applied CFD in ANSYS Fluent, 9 hours

- Domain Independence
- Grid Refinement and Independence
- Unsteady Temporal Independence
- Post-processing and Uncertainty Quantification

Advanced Topics, 6 hours

- Turbulence Modeling
- Overset Mesh
- Moving Mesh
- Other topics as time permits