THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Aerospace Engineering and Engineering Mechanics

COE 347 - INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS
SPRING 2021

SYLLABUS

Unique Number:	13970
Instructor:	Fabrizio Bisetti ASE 4.206 Phone: (512) 471 5696 Email: fbisetti@utexas.edu
Time:	Tuesday & Thursday 12:30 – 2:00 pm
Office Hours:	TBD
Location:	Zoom ID: 933 6684 3056 (requires Zoom login with utexas.edu domain) Passcode: 077151
Teaching Assistant:	Aditya Vinod (Email: vinoda@utexas.edu)
Web Page:	Canvas

Catalog Description:
Development and implementation of finite-difference schemes for numerical solution of subsonic, transonic, and supersonic flows. Emphasis on convection and diffusion equations of fluid dynamics. Evaluation of accuracy, stability, and efficiency.

Course Objectives:
Develop fundamental understanding and practical skills in the numerical solution of partial differential equations (PDE) that describe fluid flow. Utilize state-of-the-art software and computing resources for the simulation of canonical fluid flow problems.

Prerequisites:
Aerospace Engineering 211K (or 311) or Computational Engineering 211K, and Aerospace Engineering 320 with a grade of at least C- in each.

Knowledge, Skills, and Abilities Students Should Have Before Entering This Course:
Mathematics of calculus and differential equations and background in physics, fundamental fluid mechanics, basic programming and use of MATLAB software or equivalent. Beginner’s working knowledge of the Linux/Unix command line interface.

Knowledge, Skills, and Abilities Students Gain from this Course (Learning Outcomes):
Numerical simulation of fluid flow phenomena, understanding of the practical aspects of computations, stability and accuracy of numerical methods in the context of fluid flow simulations, ability to understand and interpret simulation results, and application of computational methods to solve practical fluid mechanics problems.

Impact On Subsequent Courses In Curriculum:
None.

Relationship of Course to Student Outcomes:
This course contributes to the following ABET Criterion 3 outcomes and those specific to the EAC accredited program.

Outcome	**√**	**Outcome**	**√**
a. An ability to apply knowledge of mathematics, science, and engineering	X	g. An ability to communicate effectively	X
b. An ability to design and conduct experiments, as well as to analyze and interpret data	X	h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.	
c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.		i. A recognition of the need for and an ability to engage in life-long learning	
d. An ability to function on multi-disciplinary teams	X	j. A knowledge of contemporary issues	
e. An ability to identify, formulate, and solve engineering problems	X	k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	X
f. An understanding of professional and ethical responsibility			

ABET Program Criteria Achieved:

Criterion	**√**	**Criterion**	**√**	**Criterion**	**√**
A. Aerodynamics	X	G. Orbital Mechanics		M. Preliminary/Conceptual Design	
B. Aerospace Materials		H. Space Environment		N. Other Design Content	
C. Structures		I. Attitude Determination and Control		O. Professionalism	
D. Propulsion	X	J. Telecommunications		P. Computer Usage	X
E. Flight Mechanics	X	K. Space Structures			
F. Stability and Control		L. Rocket Propulsion			

Topics:
Based on 30 Tuesday & Thursday classes.

- Introduction (1 class)
- Fundamental equations of fluid mechanics (3 classes)
- Time integration techniques (3 classes)
- Finite differences (3 classes)
- Numerical solution of the wave equation (3 classes)
- Stability and accuracy of numerical schemes (3 classes)
- The Euler equations (2 classes)
- Finite volumes (3 classes)
- Methods for compressible flows (3 classes)
- Software (OpenFOAM) learning tutorials (3 classes)
- In class exams (2 classes)

Professionalism Topics:
None.

Design Assignments:
None.

Laboratory Assignments:
The class features four tutorials (administered during lecture hours) and complete a final project requiring to execute and post-process a computational fluid dynamics (CFD) simulation. During each tutorial, the instructor and/or teaching assistant will walk the students over the material and explain key steps involved.

Computer & Software:
Solution of fluid flow equations for canonical flow configurations using the OpenFOAM open source software. Students will have the opportunity to (a) use the OpenFOAM software installed on their personal computers, (b) utilize the OpenFOAM software installed at the Texas Advanced Computing Center (TACC), or (c) the OpenFOAM software in the ASE/EM computer laboratory.

Textbooks:
- Computational Fluid Mechanics and Heat Transfer / Richard H. Pletcher, John C. Tannehill, and Dale A. Anderson, Third Ed., CRC Press 2013. *Available online via UT Library.*
- Fundamentals of Engineering Numerical Analysis / Parviz Moin. *Available online via UT Library.*
- (Optional) Computational methods for fluid dynamics / Joel H. Ferziger, Milovan Perić.

Class Format:
Lecture.

Class Schedule:
See detailed class schedule on the last page.

Class Outline:
See detailed class schedule on the last page.

Grading:
Homework (Individual) (8+1): 20%
OpenFOAM assignments (Team) (3): 20%
Exams (Individual) (2): 30%
Final Project and Presentation (Team): 30%

Team Work Grading:
Grades for Team assignments will be graded as follows. First, each assignment will be graded. Then individual grades will be obtained by weighting the assignment team grade by a factor specific to the student. The factor specific to the student is calculated from the peer rating of team members. Twice during the class, you will be asked to rate yourself and your team members with regard to the team work performed.

Homework:
Homework are an integral part of the class and learning activities and <u>are to be completed individually</u> unless otherwise noted on the homework instructions. Expect about 8 homework sets and one introductory homework. The homework sets will feature a mixture of textbook reading, online quizzes, mathematical derivations, implementation of numerical methods, and programming and analysis of simulations.

OpenFOAM assignments:
In the course of four lectures, the instructor and teaching assistant will go over OpenFOAM tutorials. The students are expected to complete the tutorials in small teams of about 3 to 4 students each and turn in one assignment per group by the due date.

Late Policy & submission:

Assignments and homework are to be turned in electronically in PDF format on Canvas by 11:59pm on the scheduled due date. If the assignment/homework requires programming, an archive of the source code should be turned in also. **Only one late submission will be accepted during the term. Should the late assignment be turned in later than 11:59pm on the second day following the due date, the submission will not be graded.**

Typewritten assignments are encouraged, but not required. Handwritten assignments are acceptable provided that they are neatly composed and scanned. Use a scanner and reduce the file to a manageable size prior to submission. Do not use a low-quality smartphone pictures of your assignment.

Examinations:
Two mid-term exams will be administered in late February and late April during class. The material covered in those examinations is as follows:

- Exam 1: introduction, fluid flow equations, time integration, finite differences
- Exam 2: the wave equation, properties of numerical schemes, finite volume, Euler equations

Final Project:
The class features a team-based final project requiring the student to design, plan, and execute a simulation using the OpenFOAM software.

The project must feature a canonical flow of interest to the students (flow around a cylinder, flow in a pipe, etc). The students will execute simulations and post-process results that illustrated and characterize the flow. Comparisons against analytical and theoretical results are highly encouraged. The project focus may be placed on the numerical methods (grid convergence, dependence of errors on time- and space-discretization) or on the physics of the problem (e.g. dependence of drag on Reynolds number).

It is suggested that the students start from an existing OpenFOAM tutorial, either from class or one of the other tutorials available online or the software distribution, and extend/modify the tutorials as needed.

Each team must choose a final project by the end of February at the latest. Students can either choose a project among those on a list (to be provided early February) or propose their own project. Either way, a short half page statement about the project is to be turned in by the end of February. Submission of the project statement is required and a short feedback will be provided to the student. The project statement will not be graded.

A final report based on the work performed within the project is to be turned in on the day of the presentation. Presentations from each team will be held during final's week.

Attendance:
Mandatory unless prior approval has been obtained from the instructor.

Office Hours:
TBD

Special Notes:
The University of Texas at Austin provides upon request appropriate academic adjustments for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4641 TDD or the Cockrell School of Engineering Director of Students with Disabilities at 471-4321.

Evaluation:
The Measurement and Evaluation Center forms for the Cockrell School of Engineering will be used during the last week of class to evaluate the course and the instructor.

A similar, anonymous online survey through Canvas will be used in the middle of the course.

Prepared by: Fabrizio Bisetti **Date:** 01/18/2021

Schedule for COA 347 - Introduction to Computational Fluid Dynamics - Spring 2021

Updated Jan 18, 2021

	January				February								March							April									May		
Day	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	T	TH	
Calendar	19	21	26	28	2	4	9	11	16	18	23	25	2	4	9	11	23	25	30	1	6	9	13	15	20	22	27	29	4	6	
Lecture #	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	
TOPIC																															
0-Introduction																															
1-Fluid flow Eqns																															
2-Time Integration																															
3-Finite differences																															
4-The wave equation																															
5-Scheme properties																															
6-Euler equations																															
7-Finite volume																															
8-Methods for compressible flows																															
9-Misc topics																															
SOFTWARE																															
OpenFOAM tutorial				1									2									3									
EVALUATION																															
In class exam																1													2		
HW due			0				1			2			3				4				5			6			7			8	
OpenFOAM assignment due									1									2										3			
Final project proposal																															
Final presentation and report																															

Note: March 15-20, 2021 Spring Break