ME 5515: COMPUTATIONAL FLUID DYNAMICS
Winter 2018 Syllabus

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Office Hours: Before or after class, available by appointment

Class Times: MW: 5:30PM – 7:17PM, 204 Dodge Hall

Textbooks: Required: *Essential Computational Fluid Dynamics*, Oleg Zikanov, John Wiley & Sons, Inc., 2010.

Computer account: An SECS computing account is required to access the CFD software. If you do not have such an account, please go to https://elara.secs.oakland.edu/SECSNetworkLogins/request.aspx

Course Prerequisites: ME5400; knowledge of a programming language (FORTRAN, C, Matlab, etc.)

Course Website: The Moodle course management system will be used this semester. You may access the ME 5515 website using your OUCA name and password at: https://moodle.oakland.edu. HW assignments, solutions, announcements, interesting web links and handouts can be found on this site. Please visit the website on a regular basis for course updates.

University Catalog Description:
Overview of the physical and mathematical foundations of computational fluid dynamics (CFD). Numerical solution techniques for the Navier-Stokes equations; finite difference and finite volume methods, including discretization, stability analysis, and time stepping; turbulence modeling; grid generation and complex geometries. Introduction to commercial CFD software. Includes projects.

Course Description:
This course will introduce the physical and mathematical foundations of computational fluid dynamics (CFD) for incompressible and compressible viscous flows. CFD is one of the modern tools, in addition to experimental and analytical methods, available to solve fluid dynamics and heat transfer problems. It relies on computer simulations to predict fluid flow phenomena. The use of CFD in industry (automotive, aerospace, biomedical, HVAC, etc.) has dramatically increased over the past few years, in large part due to its usefulness in the design process: its ability to quickly evaluate multiple designs cost-effectively can significantly reduce the "test and build" cycle. The major emphasis of this course will be placed on theoretical and "hands-on" CFD. Students will be expected to complete several computer projects, which may include writing their own CFD computer program, as well as using a commercial software package.

Course Objectives:

The primary objective of this course is to introduce the physical and mathematical foundations of computational fluid Dynamics and to provide students with a working knowledge of CFD. By the end of the course, the successful student will be able to:

1. Discuss the consistency, stability, convergence, and accuracy of various numerical approximations. (a)
2. Describe the characteristics of a turbulent flow and explain why turbulence models are needed for numerical simulations of turbulent flows. (a, e)
3. Explain the difference between finite difference and finite volume approximations. Discuss and apply different first and second order approximations. (a, e, k)
4. Describe one or more computational approaches used to solve model partial differential equations, as well as the Navier Stokes equations. Discretize these equations using finite difference or finite volume methods. (a, e, k)
5. Formulate the finite difference or finite volume discretization of a fluid mechanics problem and implement the solution algorithm in a computer program (a, b, e, g, k)
6. Use a commercial software package to numerically solve a fluid mechanics problem and analyze the results using appropriate plots and averaged quantities. (a, b, e, g, i, k)
7. Discuss the advantages and limitations of CFD as an engineering design and analysis tool. Estimate the accuracy of a numerical solution. (a, e, h, j, k)

Tentative Course Topics:

Topic / Lecture	Reading
Introduction to numerical methods; what is CFD?	Ch. 1
Review of the basic equations of fluid mechanics in integral and differential form (conservation of mass, momentum and energy)	Ch. 2
Introduction to MatLab	https://moodle.oakland.edu
Finite difference methods	Ch. 4
Finite volume methods	Ch. 5
Introduction to StarCCM+	https://moodle.oakland.edu
Steady problems: Direct and Iterative Methods	Ch. 8
Unsteady problems: Explicit and Implicit Schemes; Stability Analysis; Time Integration	Ch. 6
Navier-Stokes equations: Collocated and staggered grids; Projection/MAC method; SIMPLE scheme; Boundary conditions	Ch. 10
Turbulence modeling	Ch. 11
Complex geometries; Grid generation	Ch. 12 https://moodle.oakland.edu
Industrial Application	Ch. 13, https://moodle.oakland.edu

Course Grading:

The course grade will be determined based on homework assignments (some of which will include small programming problems, web searches or literature reviews), two exams, and three or four computer projects. One of the projects may involve programming. The remainder will use a commercial software package. Written reports will be required for all projects and will be submitted electronically on Moodle. An oral presentation will also be required for the final project.

The course grade will be calculated as follows:

Computer projects (Some may be team based):	65%
Exams	20%
Homework:	15%

It is possible for every student to obtain an A for the course. Significant improvement or decline in student performance throughout the semester will be taken into account in determining the course grade. There is no fixed grading scale for this course; a conversion formula from your percentage score to Oakland University grades will be determined at the end of the course. However, the following "standard scale" shows the lowest possible grade that a given percentage score will generally earn (the grade may be higher than this): 95%→4.0, 80%→3.0, 68%→2.0, 50%→0.0. Note that an average of 50 or less will always be considered as a failing grade, 0.0.

Important Dates:

- January 15 – MLK Day (classes not in session)
- January 18 - Last day for "no-grade" drop and last day for 100% semester refund
- February 17– February 25 – Winter recess
- March 14 - Last day for official withdrawal (W)
- April 16 - Last ME 5515 class
- April 25 - **Final Project Presentations** –7:00PM – 10:00PM

Academic Conduct:

Students are expected to read, understand and comply with the Academic Conduct Policy of Oakland University, as explained at https://oakland.edu/pace/policies-procedures. Violations will be taken before the Academic Conduct Committee. Students found guilty of academic misconduct in this course will receive a grade of 0.0 in addition to any penalties imposed by the Academic Conduct Committee. The latest version of the Academic Conduct Committee's procedures is in the Dean's office. *Note that Dr. Zeng takes violations of the Academic Conduct Policy extremely seriously!* Students caught, for example, cheating on lab reports (by copying from old lab reports), quizzes, or communicating with each other during a test if a proctor happens to step out of the room, will be dealt with aggressively. A student caught helping another student cheat (for e.g., by allowing him/her to copy off an exam) will dealt with just as aggressively as the student caught cheating.

Please note that the use of cell phones, text messaging and laptops is not allowed in this class unless you receive a special dispensation from the instructor.

<u>Program Outcomes</u>: ABET 3(a-k)

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