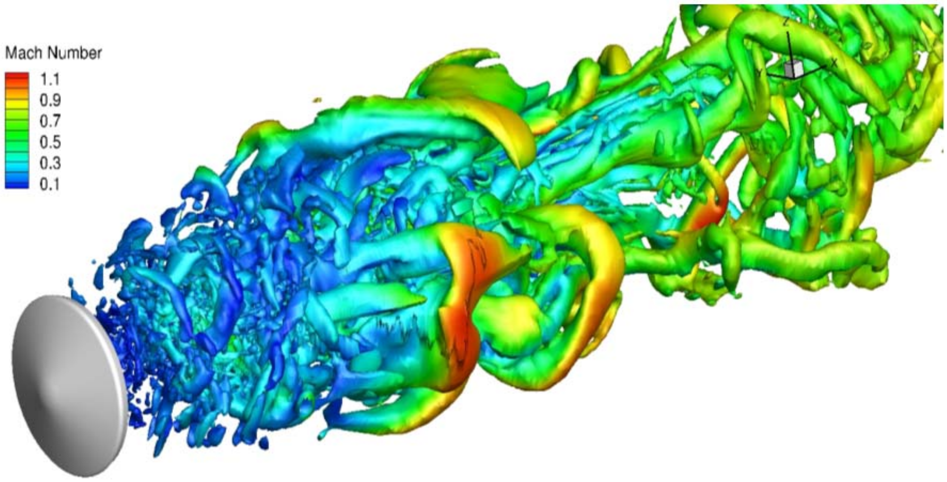
AE169: Computational Fluid Dynamics

Spring 2016
Classroom: ENG 164



Instructor Info: Dr. Michael Barnhardt
Office: E272F
650.604.0843
michael.barnhardt@sjsu.edu

Prerequisites: C- or better in Math 129A, AE160
AE164 recommended

Textbook:
There is no required textbook for this course. The following are some references you may find useful:

Numerical Computation of Compressible and Viscous Flow
Robert MacCormack
AIAA Education Series
ISBN 978-1-62410-264-6

Fundamentals of Computational Fluid Dynamics
H. Lomax, T. Pulliam, and D. Zingg
Springer
ISBN 978-3-540-41607-4
(Early editions of this manuscript can be found freely online)

Finite Volume Methods for Hyperbolic Problems
Randall Leveque
Cambridge Texts in Applied Mathematics
ISBN 978-0-521-00924-9

Description:
This course focuses on developing the mathematical foundations of computational fluid dynamics (CFD) with emphasis on applications. We start with classification of partial differential equations and how it informs discretization of governing equations. Concepts of discrete truncation error analysis and solution stability are introduced. Finally, techniques are developed for solution of the compressible Euler and Navier-Stokes equations within a finite volume framework. Students will produce their own CFD software capable of accurately simulating simple two-dimensional fluid dynamics problems.

Goals: Introduce students to basics of computational fluid dynamics and have them apply learned techniques on canonical problems.

Learning Objectives:
Students completing this course will be able to

- Classify partial differential equations according to their mathematical structure
- Discretize governing equations in space and time
- Analyze truncation errors arising from discretization
- Analyze stability of discrete approximations
- Formulate explicit and implicit integration schemes
- Formulate discrete representations of governing equations in curvilinear space
- Design functional computational fluid dynamics software
- Solve the two-dimensional Euler equations for canonical problems

Approximate Weekly Schedule:

Week	Topic
1-Feb	Introduction and Review of Governing Equations
8-Feb	Integral and Conservation Laws/Understanding the Governing Equations
15-Feb	Numerical approximation and Stability
22-Feb	*Guest Lectures*
29-Feb	Transonic Small Disturbance Equation
7-Mar	Finite Volume Approach
14-Mar	Algorithms for Solving the Euler equations
21-Mar	Algorithms for Solving the Euler equations
28-Mar	*Spring Break*
4-Apr	Boundary Conditions
11-Apr	Explicit vs. Implicit methods
18-Apr	Multi-dimensions and curvilinear transformations
25-Apr	Navier-Stokes Equations and Algorithms
2-May	Navier-Stokes Equations and Algorithms

9-May	Advanced Topics in CFD
16-May	Advanced Topics in CFD

Project:
The bulk of work in this course will consist of designing, implementing, and executing a functional two-dimensional solver for the Euler equations. Assignments will be introduced at appropriate intervals to motivate implementation of important modules: Input/output, data structures and initialization, boundary conditions, flux calculation, time integration, and more. We will conduct a mid-semester code review to ensure proper progress is being made and to help improve functional aspects of your software. **At the end of the semester, a final report will be submitted (along with your code) detailing its structure and showing results for a few pre-selected problems.**

This course requires extensive coding. You may use any programming language you are comfortable with, however it is strongly encouraged to use a standard compiled language for performance reasons. MATLAB may get the job done but it is *SLOW*. Unless otherwise instructed, you are ***not*** allowed to use canned/pre-packaged routines (such as ODE/PDE solvers). Please start working on programming assignments well in advance of the due date: debugging code can be time consuming. As a matter of policy, outside of the mid-semester and final review, the instructor will ***not*** look at your code.

Finally, you are permitted (though not required) to work in teams of two people if you wish. If you choose to do so, you must make clear the contributions of each team member through appropriate attribution in the source code and final report.

Grading:
Grade evaluations for this course will be earned based on performance on assignments and the course project. The final report will constitute your final exam, ***DUE on 5/18**. **Late assignments will not be accepted.***

Scoring will be divided as:

- Homework (200 points)
- Mid-semester review (200 points)
- Final project report (600 points)

The following grading scale is tentative and may be revised after the mid-semester review:

950 points	<	A+
900 points	<	A
850 points	<	A-
800 points	<	B+
750 points	<	B
700 points	<	B-
650 points	<	C+

600 points	<	C
550 points	<	D
Below	=	F

Additionally, extra credit can be obtained through the following means:

1. Attend an Advanced Modeling and Simulation seminar and submit a 1-2 page report summarizing the topics covered. The seminar is sponsored by the NASA Advanced Supercomputing Division and can be viewed online through the following web address:

   https://www.nas.nasa.gov/publications/ams/ams.html

   New seminars are typically held weekly. Past seminars are posted and equally acceptable for extra credit. Each report is worth up to 50 points, with a maximum of three reports per student.

2. Added project features beyond the baseline, such as
   a. Alternative flux schemes
   b. Implicit time integration
   c. Viscous model
   d. Turbulence model
   e. Thermochemical non-equilibrium

   Features are worth up to 100 additional points each. ***To receive credit, functionality must be demonstrated in the final report.***

The maximum attainable number of points in this course is 1000.