

ENAE 685 - Computational Fluid Dynamics II

Spring 2009

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Classroom: MTH B0425



Room: 3170 Eng. Class. Bldg.
Office Hours: M/W 1-3 pm; Fr 9-10 am
Blackboard: <http://bb.eng.umd.edu>
Class time: Tu. / Th. 11:00 am -12:15 pm

Grading:

Homework & Computer Projects	50%	Midterm/(Project?)	25%
Term Project	25%		

Homework will be due at *beginning* of class of the due date, unless stated otherwise.

Any homework handed in less than 2 days late will automatically receive 75% of normal grade.

Any poorly done homework will be returned with a request for the homework to be redone.

Background Assumed:

Math - linear algebra, calculus, complex variables, ODE, and PDE

Physics - some understanding of incompressible and compressible fluid flow

Computing - FORTRAN (or another modern language), MATLAB, editors, plotting

Numerical methods - basic theories of stability, accuracy (ENAE684)

Textbook:

Handouts and Class Notes

What is Computational Fluid Dynamics (CFD)?

CFD is a tool, similar to experimental tools, used to gain greater physical insight into problems of interest. CFD is the numerical solving of partial differential equations on a discretized system that given the available computer resources best approximates the real geometry and fluid flow phenomena of interest.

Planned Topics

ENAE684 *emphasized the theoretical basis for the numerical methods* used in CFD with applications to representative simplified scalar linear problems that were unsteady and 1-D. The extension to multi-dimensional and nonlinear problems was briefly discussed. This semester will emphasize applications and implementations of CFD methods. The fluid physics of each of these areas will be covered as appropriate, as well as the assumptions and limitations of the various methods. Specifically:

1. For the first couple of weeks the theoretical development of iterative methods will be covered, as applied toward elliptic problems and implicit methods.
2. These iterative methods will then be extended to handle nonlinear flow, especially the case of mixed hyperbolic/elliptic systems that exists in 2-D steady transonic flow. The application will be to solving the transonic small disturbance equation about a 2-D airfoil using successive line over-relaxation. Full potential methods will be discussed.
3. We will examine the generation of curvilinear grids in multiple dimensions. This will involve the use of coordinate transformations and result in equations that incorporate curvilinear grids through the appearance of grid metrics. Furthermore, there will be a discussion of the merits of various approaches to generating the grids as well as the coupling of grid systems to handle complex geometries. The application will be towards generating a 2-D curvilinear grid about an airfoil or inside a nozzle by solving PDE's or using algebraic methods.
4. We will examine the application to systems of equations, such as the Euler equations. This will include the development of explicit and implicit methods that can handle hyperbolic

equations with characteristics of mixed signs. We will also examine allowable jump conditions for hyperbolic systems. Quasi 1-D flow through nozzles and/or shock tubes will be examined.

5. Time permitting: low Mach number preconditioning, viscous effects and 2-D problems will be investigated.

6. A paper and/or project of the student's choosing will be developed and presented to the class.

A final project will be written up as well as presented to the class. It is expected that this project, of the students choosing (in consultation with the professor), will go past the material required for the other assigned computer problems.

Learning Outcomes

1. Students will have a basic knowledge of the essential elements (governing equations, meshing, discretization schemes, etc.) involved in computational fluid dynamics.
2. Students will be able to understand and apply the basic concepts of stability, consistency and convergence as they apply to the numerical solutions of partial differential equations.
3. Students will have a thorough ability to apply Fourier Stability Analysis to numerical schemes common in fluid dynamic applications, as well as determine the influence of various boundary conditions on stability. Furthermore, they will be able to determine how to modify their differencing scheme in order to obtain the desired stability and accuracy properties.
4. Students will have an introductory knowledge of methods used to solve nonlinear system of equations iteratively.
5. Students will have a conceptual understanding of various grid generation techniques and be able to generate 2-D curvilinear meshes.
6. Students will be able to develop numerical algorithms for systems of equations, including the incorporation of proper boundary conditions.
7. Students will be able to write, debug and test complicated computer programs that implement the CFD techniques as well as analyze the results and be able to perform written reports and oral presentations.
8. Students will have a desire to understand further concepts in computational fluid dynamics, especially as concerns the modeling of systems of equations typical in aerodynamics: the Euler and Navier-Stokes equations in multi-dimensional space on arbitrary mesh systems.

Code of Academic Integrity

The University of Maryland, College Park has a nationally recognized Code of Academic Integrity, administered by the Student Honor Council. This code sets standards for academic integrity at Maryland for all undergraduate and graduate students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit <http://www.shc.umd.edu>.

To further exhibit your commitment to academic integrity, remember to sign the Honor Pledge on all examinations and assignments: "I pledge on my honor that I have not given or received any unauthorized assistance on this examination (assignment)."