

# Computational Fluid Dynamics

AOE 6145, Spring 2011

Tu-Th 9:30-10:45am, Randolph Hall, Room 110

**Course Description:** This course offers topics of advanced study in the numerical solution to compressible fluid flow problems.

## Prerequisites:

- AOE 4984/5984: Intro CFD (or equivalent)
- AOE 5184: Advanced Aero and Hydrodynamics (or equivalent)
- MATH 3144: Linear Algebra (or equivalent)
- or permission of instructor

**Textbook:** C. Hirsch, *Numerical Computation of Internal and External Flows*, Vol. 2: Computational Methods for Inviscid and Viscous Flows, John Wiley & Sons, New York, 1988.

**References:** J. D. Anderson, *Computational Fluid Dynamics: The Basics with Applications*, McGraw-Hill, 1995 (**book from Intro. CFD class**).

J. C. Tannehill, D. A. Anderson, and R. H. Pletcher, *Computational Fluid Mechanics and Heat Transfer*, 2<sup>nd</sup> ed., Taylor and Francis, Philadelphia, 1997.

D. D. Knight, *Elements of Numerical Methods for Compressible Flows*, Cambridge University Press, New York, 2006.

J. H. Ferziger and M. Peric, *Computational Methods for Fluid Dynamics*, 3<sup>rd</sup> Ed., Springer-Verlag, Berlin, 2002.

C. Hirsch, *Numerical Computation of Internal and External Flows*, 2<sup>nd</sup> Ed. (Vol. 1), Elsevier, 2007.

W.L. Oberkampf and C.J. Roy, *Verification and Validation in Scientific Computing*, Cambridge University Press, Cambridge, 2010.

**Instructor:** Dr. Chris Roy, Associate Professor, Aerospace and Ocean Engineering Dept.

**Prerequisites by Topic:** Governing equations for fluid dynamics, partial differential equations, introductory CFD, linear algebra

## Topics:

1. Review of the basics of CFD
2. Euler equations: focus on 2D/axisymmetric form
3. Discretization approaches: focus on the finite volume method
4. Code verification review
5. Characteristic decomposition of the Euler equations: flux Jacobians, Eigenvalue analysis, similarity transformations, compatibility relations
6. Upwind schemes: approaches, second-order methods ( $\kappa$ -schemes), flux limiters, low dissipation schemes

7. Temporal integration methods: explicit, implicit, time accuracy
8. Mesh transformations
9. Solution verification review
10. Navier-Stokes equations in 2D/axisymmetric form
11. RANS turbulence modeling
12. CFD applications: Fluent
13. Advanced topics – time permitting (e.g., preconditioning, multigrid methods, parallel computing via MPI, unstructured grids, nondeterministic simulations)

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|-----------------|----------|---|
| <b>Grading:</b> | Test 1   | 15%   |
|                 | Test 2   | 15% (not cumulative)                        |
|                 | Homework | 30% (includes some programming assignments) |
|                 | Project  | <u>40%</u>                                  |
|                 | Total    | 100%  |

**Project:** While a number of smaller programming assignments will be given as part of the homework, an individual project will also be assigned during the semester. The choice of programming language is left up to you; however, the instructor will be able to help with programming language syntax mainly for Fortran. The other recommended programming language is C. While C++ is probably fine too (although I recommend you stay away from object oriented paradigms for this project), I do not recommend you using Matlab since it will likely run much slower (factor of 10?) than both Fortran and C/C++. A very good Fortran 90/95 textbook is: Stephen J. Chapman, *Fortran 90/95 for Scientists and Engineers*, 2<sup>nd</sup> Ed., McGraw-Hill, Boston, 2004.

**Office Hours:** I prefer that you come in during office hours; however, if my office door is open then I am usually free to answer questions.

Dr. Chris Roy, Rm. 330 Randolph Hall, 231-0080, [cjroy@vt.edu](mailto:cjroy@vt.edu)  
Office Hours: TBD

**Test/Exam Policy:** All tests and exams will be open notes and open book.

**Class Web Page:** via Scholar (<http://learn.vt.edu/>)

**Attendance Policy:** You are expected to attend all class lectures.

**Special Needs:** Students who need accommodations are asked to arrange a meeting with me during office hours the first week of classes, or as soon as possible if accommodations are needed immediately. If you have a conflict with my office hours, an alternate time can be arranged. To set up this meeting, please contact me by Email.