ME-561
An Introduction to
Computational Fluid Dynamics for Incompressible Flow

Fall Semester, 2002

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Prerequisites: ME428/528, ME530, or permission of instructor

Lectures: T Th 3:30 – 4:45 PM, Room 214, Mechanical Engineering

Office Hours: before/after class Thursday's, or e-mail

URL: `http://www.me.unm.edu/~christon/me561/me561.html`

Text Book (Optional): P. M. Gresho and R. L. Sani, "Incompressible Flow and the Finite Element Method – Volume Two, Isothermal Laminar Flow," Wiley, 2000.

Grading: Homework Problems – 10%
3 Programming Exercises & Technical Reports – 45%
Mid Term Exam – 20%
Final Exam – 25%
A grade of 80% or above on the final exam is required for an A in the course.

References:

P. M. Gresho and R. L. Sani, "Incompressible Flow and the Finite Element Method – Volume One, Advection-Diffusion," Wiley, 2000.

J. N. Reddy and D. K. Gartling, "The Finite Element Method in Heat Transfer and Fluid Dynamics", 2nd Ed., CRC Press, 2000.

O. C. Zienkiewicz and R. L. Taylor, "The Finite Element Method", 4th Ed., vol. 2, McGraw-Hill, 1994.

C. Hirsch, "Numerical Computation of Internal and External Flows", Wiley, 1988.

D. A. Anderson, J. C. Tannehill, and R. H. Pletcher, "Computational Fluid Mechanics and Heat Transfer", Hemisphere Publishing, 1984.

T. J. R. Hughes, "The Finite Element Method", Prentice-Hall, 1987.

E. Becker, G. F. Carey and J. T. Oden, "Finite Elements an Introduction", Prentice Hall, 1981.

Topics

1. Fluid Dynamics and Finite Element Fundamentals

   The Basic Equations of Fluid Dynamics
   Physical and Mathematical Classification of PDE's
   The Finite Element Weak Form and Weighted Residual Formulations
   FE Matrix Equations, Anatomy of an FEM Code

2. The Advection-Diffusion Equation

   Advective and Divergence Forms
   Finite Element and Finite Volume Formulations
   Semi-Discrete FE Equations and Boundary Conditions
   Mass Lumping and Reduced Integration
   Explicit and Implicit Time Integrators
   Numerical Dispersion and Dissipation

3. The Navier-Stokes Equations

   The Continuum Equations – Stress-Divergence, Div-Curl, etc.
   The $u - P$ Equations and Boundary Conditions
   The Pressure Poisson Equation
   Boundary Conditions and Initial Conditions
   The Well-Posed Initial Boundary Value Problem

4. Solution Methods for the Time-Dependent Equations

   The $u - P$ Formulation
   DAE's are NOT ODE's
   An Explicit Algorithm
   The Helmholtz Decomposition
   The Semi-Implicit Projection Algorithm
   The Fully-Implicit Projection Algorithm

5. Element Technology and Pressure and Advective Stabilization

   Choices of Elements
   Null Spaces and Pressure Modes
   LBB-Stability/div-Stability)
   Pressure Stabilization Concepts
   Advective Stabilization

6. Vorticity Methods (Time Permitting)

   The Vorticity Form of the Navier-Stokes Equations
   The Generalized Helmholtz Decomposition (GHD)
   A Galerkin GHD Formulation
   Multipole-Acceleration of Domain Integrals