Syllabus

MAE 4131-001/MAE 5131-001
Introduction to Computational Fluid Dynamics (CFD)
Meets: TR 4:30 to 5:45 p.m. in UH 317

University of Colorado at Colorado Springs
Mechanical and Aerospace Engineering

Instructor: Dr. Jason Roney
Office: 231 University Hall
Telephone: (719) 262-3573
Email: jroney@eas.uccs.edu

Level: Technical Elective or Introductory Graduate Course in Special Topics.

Summary of Content :
This course will introduce the student to computational fluid dynamics. The course will be an overview of underlying fundamental numerical solution methods for fluid flow problems. Specific discretization techniques and solution algorithms will be studied for linear hyperbolic(wave equation), parabolic (heat equation), and elliptic equations; for convection-diffusion equations; and for non-linear equations. In addition, the student will use a commercial CDF software to solve fluids problems.

Objectives:

1. Program fundamental numerical solution techniques used to solve fluid mechanic problems.

2. Speak intelligibly about Computational Fluid Dynamics solutions.

3. Set-up CFD problems using a standard CFD package.

4. Identify the types of P.D.E. equations solved in CFD problems.

5. Interpret the physical nature of their CFD solutions.

Prerequisites: MAE 3130 Fluid Mechanics, this course should be a senior/junior level technical elective (second course in fluid mechanics). Knowledge of a programming language, Fortran, Basic, C, C++, or the ability to program in MATLAB® will be required. The commercial package STAR-CCM+/STAR-Design will be used secondary to developing fundamental skills in CFD through programming and solving fundamental problems.

Textbook: Anderson, John, A., Jr.., Computational Fluid Dynamics: The Basics with Applications, McGraw Hill Publishing, 1995.

Important Dates:
First Day of Class: Tuesday, August 22, 2006
No Class: November 23, 2006
Last Day of Class: Thursday, December 7, 2006
Final Exam Period: Monday, December 12, 2006, 4:30 to 7:05 p.m.

Grading: Homework*[1]: 40%
Projects: 40%
Final Project Presentation: 10%
Quizzes*[2]: 10 %

*[1]Homework will be due at the beginning of class on the due date. Late policy: 50% off, one day late, and will not be accepted 2 days late. Homework will be assigned in class and then posted on the website. Homework will be an invaluable learning tool to learn the concepts and it is encouraged that students work individually, only consulting class mates after a legitimate attempt at solving the problems has been made.

*[2]Quizzes will be announced a week in advance and will cover general terminology and concepts associated with CFD (short answer and fill in the blank). Typical time allotted for the quizzes will be 10 to 15 minutes at the beginning of class. Approximately 2-3 quizzes will be given.

At times, the graduate students taking the course will be expected to do more “challenging” course work designated by “G” on the problem. The undergraduates may do these problems as extra credit if they choose.

There will be no mid-term or final, but rather a final project presentation during the Final Exam Period. During this time, each student will have 10 to 15 minutes to present their final project. The hope is the student will convey the knowledge they have learned about CFD in the presentation of their project. The presentation itself is worth 10% of the students’ grade. For the final project, the student may choose from a list of projects or may come up with their own (the topic must be approved). The report, separate from the presentation, will count as part of the “Projects” grade. There will be 3 programming projects during the semester that are part of the “Projects” grade.

Proposed Outline of Topics:

1. Governing Equations of Fluid Motion for CFD

2. Overview of Partial Differential Equations
    a. Integration of O.D.E.’s
    b. Hyperbolic Equations
    c. Parabolic Equations
    d. Elliptic Equations

3. Basic Numerical Discretization
    a. Finite Differences
    b. Explicit versus Implicit Form
    c. Stability Analysis

4. Grids for CFD
    a. Transformation of Equations
    b. Stretched Grids
    c. Adaptive Grids
    d. Boundary Fitted Grids

5. Introduction to CFD Software (STAR-CCM+)

6. Linear Hyperbolic Equations
    a. Implicit Scheme
    b. Lax-Wendroff's Method
    c. MacCormack's Method
    d. ADI Method

7. Linear Parabolic Equation
    a. Implicit Method
    b. Combined Method A
    c. Crank-Nicolson
    d. ADI Method

8. Linear Elliptic Equation
    a. Jacobi
    b. Gauss-Siedel
    c. Successive-Over-Relaxation

9. Convection -Diffusion Equation
    a. FTCS Method
    b. Box Method
    c. Mixed Schemes
    d. Leap Frog Schemes

10. Non-Linear Equations
    a. Newton's Method
    b. Fixed Point Method

11. Overview of Turbulence Modeling for CFD