Introduction

Computational Fluid Dynamics (CFD) involves numerical integration on a computer of the governing equations of fluid dynamics and heat transfer, which in general form a non-linear system of partial differential equations (PDEs). The general procedure involves discretization of the continuous physical domain into a mesh or grid of points and the relevant governing PDEs for the problem of interest into a system of algebraic equations for the values of the dependent flow variables, subject to appropriate initial and boundary conditions, on each of discrete grid points in space as a function of time. There are a wide variety of possible discretization schemes available including finite difference, finite volume, and finite element, as well as spectral methods, each involving a different type of trade-off with regard to various aspects of accuracy and efficiency.

CFD expertise requires knowledge of fundamental fluid dynamics and heat transfer and related physics, theoretical and applied mathematics and analysis, basic and advanced numerical methods and scientific computing. Challenges remain with regard to providing accurate and efficient algorithms for complex multi-physics flow problems involving turbulent flows, combustion, multiphase flow, and acoustics, as well as fluid-structure interaction problems, in complex geometries.

Course Description

This course offers an introduction to CFD with an emphasis on finite-difference and, to a lesser extent finite-volume and finite element methods. It is comprehensive in that it begins with classification of PDEs and basic representations of derivatives via finite-difference approximations and proceeds to consider discretization for model PDEs, the Euler equations for inviscid flow, and the incompressible and compressible Navier-Stokes equations. Both basic and advanced methods, including introductions to high-order, high-resolution, advanced upwind schemes, and grid generation methods, are covered. Computer assignments offer a unique hands-on learning experience for the student.

Course catalog description

"Introduction of finite difference, finite volume, and finite element methods for incompressible flows and heat transfer. Topics include explicit and implicit schemes, accuracy, stability and convergence, derived and primitive-variables formulation, orthogonal and non-orthogonal coordinate systems. Selected computer assignments from heat conduction, incompressible flows, forced and free convection"

Course schedule

Tuesday & Thursday, 10:00-11:20AM, Ferry Hall 112
Office Hours: Tuesday & Thursday, 12:30-2:00PM, 103 Light Engineering
Email: zvi.bar-yoseph@stonybrook.edu
Course Topics:

Below is an itemized list of the main topics to be covered in this class:

- ✔ Introduction to CFD
- ✔ Classification of Partial Differential Equations (PDEs)
- ✔ Basic of Discretization Methods: Finite-Difference, Finite Volume and Finite Element Methods
- ✔ Application of Numerical Methods to Simplified Model Equations:
  - Numerical Methods for Elliptic PDEs [Laplace's Equation]
  - Numerical Methods for Parabolic PDEs [Heat Equation]
  - Numerical Methods for Linear Hyperbolic PDEs [Wave Equation]
  - Numerical Methods for Nonlinear PDEs [Burgers' equation (Viscous & Inviscid)]
- ✔ Governing Equations of Fluid Dynamics and Heat Transfer
- ✔ Numerical Methods for Euler Equations
- ✔ Numerical Methods for Compressible Navier-Stokes Equations
- ✔ Numerical Methods for Incompressible Navier-Stokes Equations
- ✔ Handling Complex Geometries and Introduction to Grid Generation
- ✔ Advanced Topics

Course Learning Outcomes

Upon successful completion of this course, the student will be able to:

- ✔ Identify and classify partial differential equations into elliptic, parabolic and hyperbolic types.
- ✔ Understand the mathematical nature of the flow equations and their initial and boundary conditions.
- ✔ Understand, develop, and apply basic discretization techniques (finite difference and finite volume discretization schemes) to numerically solve the governing equations for two-dimensional (compressible and incompressible) flow and heat transfer problems.
- ✔ Appreciate the importance and implications of consistency, stability, convergence, and error analysis of numerical schemes.
- ✔ Understand how grids are generated.
Coursework will be weighted as follows:

Midterm exam (Thursday, March 24): 30%; Final exam: 30%;

Homework: 20%; Computer Assignments: 20%.

Student Attendance (Extra Credit): A maximum of 10% on top of the total grade provided that all course requirements were completed with a passing grade or higher.

**No Late Homework / Assignment Will Be Accepted** – Homework / Assignment is to be done individually. Homework / Assignment must be neat and orderly so that your work can be followed clearly. Solutions which are not clearly written and easy to follow (based on the judgment of the instructor) will not be graded.

**DISABILITY SUPPORT SERVICES (DSS) STATEMENT (must be the following language)**

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Disability Support Services, ECC (Educational Communications Center) Building, room128, (631) 632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.

[In addition, this statement on emergency evacuation is often included, but not required: Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and Disability Support Services. For procedures and information go to the following website: http://www.stonybrook.edu/ehs/fire/disabilities ]

**ACADEMIC INTEGRITY STATEMENT (must be the following language as approved by the undergrad council):**

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at http://www.stonybrook.edu/uaa/academicjudiciary/

**CRITICAL INCIDENT MANAGEMENT (must be the following language as approved by the undergrad council):**

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Judicial Affairs any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures.