MEEN/NUEN 644 NUMERICAL HEAT TRANSFER AND FLUID FLOW
Spring 2019

Class: TR – 8:00 – 9:15 a.m. **Location:** ZACH 361
Office: TR – 9:30 – 10:30 a.m. **Location:** ZACH 500G

Instructor: Dr. N. K. Anand
Professor of Mechanical Engineering
Department of Mechanical Engineering
Telephone No.: 845-5633
E-Mail: nkanand@tamu.edu

Alternate Instructor: Mr. Byung-Hee Choi
E-mail: bagbagwan@tamu.edu

Course Objective: The main objective of this course is to teach theory associated with finite volume techniques and SIMPLE family of methods to solve elliptic and parabolic heat transfer and fluid flow problems. Students are required to develop computer codes to solve 2-D, laminar fluid flow and heat transfer problems. The course will focus equally on Why and How issues.

Course Policy: Students are required to work individually on their computer programming projects and all homework assignments. While discussions among students are encouraged, "work for grade" must be original. All homework assignments and computer programming projects will be accepted electronically through eCampus. If there is a special circumstance that prevents you from submitting your work electronically, please contact me. All "work for grade" are due on the specified due date and delaying submission will cost your grade -10% per class.

UNIT 0 - REVIEW

† Iterative techniques to solve linear algebraic equations -- Jacobi Iteration; Gauss-Seidel Procedure; Successive Over and Under-Relaxation Techniques; Tri-Diagonal Matrix Algorithm (TDMA); and † Cyclic Tri-Diagonal Matrix Algorithm (CTDMA). Block Correction -- Ordinary Differential Equations -- Initial Value and Boundary Value Problems -- Concepts of Implicit; Explicit and Semi-Implicit Formulations. Partial Differential Equations -- Definitions and Classification. Errors, Convergence, Grid Convergence Index, and Grid Independence. † (Instructor's handout will be distributed. Students are expected to read and learn on their own).

UNIT 1 - DIFFUSION

Development of discretization equations using the Finite Volume technique. Four Basic Rules; Scarborough Criteria; Source Term Linearization. Discretization of Computational Domain. Development of Discretization Equations for Steady and Transient Diffusion Problems. Implementation of Boundary Conditions. Line by line, and point by point techniques to solve 2-D Problems. **(6 hours)**

UNIT 2 - CONVECTION-DIFFUSION

1-D Convection-Diffusion Equations - Central Difference Scheme; Up-Wind Scheme; Hybrid Scheme and Power Law. False Diffusion - QUICK Scheme. Generalized Formulation - Properties of A and B Coefficients. Development of Discretization Equations for 2-D Convection - Diffusion Problems. Treatment of symmetrically and asymmetrically positioned blockages inside the flow domain. Dominant source term technique, harmonic mean method to treat interface property. Treatment of all three types of boundary conditions with special attention to out-flow boundary conditions. **(8 hours)**

UNIT 3 - FLOW FIELD

†Advantages and Disadvantages of Vorticity-Stream Function Technique. Primitive Variable Approach. Staggered and Non-Staggered Grid Concept - Motivation - Grid Layout and Numbering for 2-D Domains. Discussion on Relative Nature of Pressure Field and Boundary Conditions for Pressure and Pressure Correction Equations. SIMPLE Family of Algorithms - Implementation, Merits, and Demerits of SIMPLE; SIMPLER; SIMPLEC; and SIMPLEX. Convergence Criteria - Absolute and Relative. **(7 hours)**

UNIT 4 - APPLICATIONS

Code Development for 2-D Steady Laminar Flow Problems in Cartesian Coordinates - Velocity and Temperature Driven Cavity; Channel Flow and Heat Transfer; natural convection in a square cavity; and Flow and Heat Transfer in Channels with Expansions (backward facing step).

Turbulence Modeling - A Brief Review - Prandtl Mixing Length Theory - One and Two (k-ε) Equation Models - Algebraic Stress Model - Reynolds' Stress Model - Large Eddy Simulation (LES) - and Direct Numerical Solution (DNS). **(8 hours)**

UNIT 5 - PERIODICALLY FULLY DEVELOPED FLOW (PDF) AND HEAT TRANSFER

Motivation - Applications - Theory and Development of PDF and Heat Transfer, Derivation of PDF Equations for 2-D Problems in Cartesian Systems. Derivation of Energy Equation for UWT; UHF: and Constant Volumetric Source type heating conditions. † PDF Heat Transfer with Conducting Blockages - Second Source Term. Relevance of the Second Source Term in Turbulent Flows. **(3 hours)**

UNIT 6 – SPECIAL TOPICS

Implicit and explicit techniques to simulate unsteady flows, Runge-Kutta Implicit Methods, Control Volume based Finite Element (CVFEM) methods, Validation and Verification, Grid Convergence Index. **(3 hours)**

UNIT 7 - ITERATIVE METHODS FOR ALGEBRAIC EQUATIONS

Basic iterative methods. Convergence analysis of iterative schemes. Estimation of convergence rate. Eigen Value analysis of iterative methods. Preconditioning techniques. The multi-grid method. **(3 hours)**

TEXT

Patankar, S.V., 1980, "*Numerical Heat Transfer and Fluid Flow*," McGraw-Hill Book Co., NY.

REFERENCES

Ames, W.F., 1977, *"Numerical Methods for Partial Differential Equations,"* Second Edition, Academic Press, NY.

Hirsch, C., *"Numerical Computation of Internal and External Flows,"* Vol. 1 and 2, John Wiley, 1988.

Minkowycz, W.J., Sparrow, E.M., Schneider, G.E., and Pletcher, R.H., *"Handbook of Numerical Heat Transfer,"* John Wiley, 1988.

Hackbusch, W., "Iterative Solution of Large Sparse System of Equations," Springer-Verlag, 1994.

Numerical Heat Transfer, Part A and B, Hemisphere Publishing Company.

Journal of Computational Physics, Academic Press.

† *Handouts prepared by the Instructor will be posted on eCampus.*

- Exam #1 February 14 (20%)
- Exam #2 March 26 (20%)
- Exam #3 April 25 (15%)
- Take Home Finals Due on the Final Exam Day, May 3, 1:00 p.m. -3:00 p.m. (15%) 1
- Homework Projects and in Class Quizzes (30%) 3

Note: A portion of Exam #2 may be Take-home. All exams are in-class, closed book, and comprehensive.

Americans with Disabilities Act (ADA) Policy Statement

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe, you have a disability requiring an accommodation, please contact the Department of Student Life, Services for Students with Disabilities, in Room 126 of the Koldus Building or call 845-1637.

Academic Integrity Statement

Aggie Honor Code: ***"An Aggie does not lie, cheat, or steal, or tolerate those who do."***

It is the responsibility of students and instructors to help maintain scholastic integrity at the university by refusing to participate in or tolerate scholastic dishonesty (*Student Rule 20. Scholastic Dishonesty, http://student-rules.tamu.edu*). New procedures and policies have been adopted effective September 1, 2004. Details are available through the Office of the Aggie Honor System (http://www.tamu.edu/aggiehonor/). An excerpt from the Philosophy & Rationale section states:

"Apathy or acquiescence in the presence of academic dishonesty is not a neutral act -- failure to confront and deter it will reinforce, perpetuate, and enlarge the scope of such misconduct. Academic dishonesty is the most corrosive force in the academic life of a university."