AE 6042
COMPUTATIONAL FLUID DYNAMICS

Catalog Description: Finite-difference, finite-volume methods for solution of Navier-Stokes and Euler Equations. Classification of equations, stability, grids, boundary conditions, implicit and explicit methods, turbulence modeling. Units = 4-0-4.

Prerequisites: AE 3450 or consent of the School
Knowledge of incompressible and compressible fluid dynamics
Proficiency in a computer programming language (e.g. C+, FORTRAN, ...)

Primary Text: Computational Fluid Mechanics and Heat Transfer, Third Edition, Pletcher, R.H., Tannehill, J.C., and Anderson, D.A., CRC Press: Taylor and Francis Publishers, 2013.

COURSE OUTLINE

TOPICS	SECTIONS
Introduction	Chapter 1
Computational Grids	
Generalized transformation and Euler Equations	5.1.7, 5.6 intro, 5.6.2
Basic requirements, and terminology	10.1
Basic types: algebraic, elliptic, hyperbolic, unstructured	10.2 to 10.7, 4.3 to 4.3.3
Introductory Discrete Modeling	
Taylor Series Expansions	3.1, 3.2
Governing Equations	
Navier-Stokes eqns in differential and integral forms	5.1 to 5.1.4
Turbulence treatment: Direct Simulation, LES, RANS	5.2
Non-dimensionalization	5.1.8
Thin-Layer Navier-Stokes (TLNS)	8.1, 8.2
Parabolized Navier-Stokes (PNS)	8.3 to 8.3.4
Euler Eqns, Full Potential Equations, Laplace Eqns	5.5 to 5.5.8
Conservation Law Form	3.3.7
Mathematical Classification of Equations	2.1 to 2.5
Model Equations and Domains of Dependence	2.6

Discretization in Time and Space	
Finite difference vs finite volume approach	5.7 to 5.7.2
Consistency, Convergence, Stability	3.3 to 3.3.6
Explicit and Implicit formulations of model equations	
Fourier or von Neumann Stability Analysis	3.7 to 3.7.2

TOPICS	SECTIONS (3RD Edition)
Solution of 1-D, Unsteady Parabolic and Hyperbolic Equations	
1-D Formulations: FTCS (Explicit), 1st Order Upwind, Lax Method	4.1 to 4.1.5
Modified Equation and Artificial Viscosity	
Lax-Wendroff, MacCormack, & Runge-Kutta Schemes	4.1.6 to 4.1.14
Solution of the 2-D, Unsteady Euler Equations	
Lax-Wendroff Scheme	
MacCormack's Scheme	9.1 to 9.2.2
Runge-Kutta Schemes	
Steger & Warming, van Leer, MUSCL Differencing	6.4
Roe's Approximate Riemann Solver	6.5 to 6.6
Total Variation Diminishing Schemes (TVD)	4.4.12
Limiters, explicit and implicit formulations	
Implicit upwind schemes: Alternating Direction Implicit (ADI), Lower-Upper (LU), and Approximate Factorization (AF) methods	9.2.3 to 9.2.6
Boundary Condition Treatment	
Inflow/Outflow boundaries: Characteristic boundary conditions, Compatibility relations	6.7
Solid wall and symmetry boundaries: Slip and no-slip conditions, Adiabatic and isothermal conditions	
Discrete modeling of viscous terms	
RANS Turbulence Modeling	
Turbulent viscosity and turbulent shear stress	5.4
Algebraic Methods: Prandtl-van Driest, Cebeci-Smith, and Baldwin-Lomax models	