Introduction to CFD - Video course

COURSE OUTLINE

Representation of mathematical ideas on the computer: numbers, functions, derivative, differential equations.

Simple problems: Solution to Laplace's equation, one-dimensional first order wave equation, heat equation, Finite difference schemes - stability and consistency, dissipation dispersion, finite volume method.

One-dimensional Euler's equation: Discretisation, Delta form, application of boundary conditions.

Advanced topics: Roe's averaging, Multigrid Methods, SOR and variational techniques.

COURSE DETAIL

S.No	Topic Title	Topic Details
1	Introduction	Overview of the course.
2	Representation - I	Need to represent functions on computers.
3	Representation - II	Introduce box functions.
4	Representation - III	Intro to hat functions.
5	Representation - IV	Demo representation of sinx using hat functions: Aliasing, high frequency, low frequency. Representation error as a global error. Derivatives of hat functions, Haar functions.
6	Representation - V	Taylor's series, truncation error, representing derivatives.
7	Representation - VI	Derivatives of various orders.
8	Simple Problems - I	Laplace's equation, discretisation, solution.
9	Simple Problems - II	Demo of solution to Laplace's equation. Properties of solution - maximum principle. Proof of uniqueness. Convergence criterion, Jacobi, Gauss-Seidel.

NP-TEL

NPTEL

http://nptel.iitm.ac.in

Aerospace Engineering

Pre-requisites:

1. Calculus, Matrix Algebra, Computer Programming and Fluid Mechanics.

Coordinators:

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10	Simple Problems - III	Initial condition change for faster convergence, hiearchy of grids, SOR.
11	Simple Problems - IV	System of equations, Solution techniques, explanation of SOR- minimization.
12	Simple Problems - V	Matrices, eigenvalues, eigen functions, fixed point theory, stability analysis.
13	Simple Problems - VI	Neumann boundary conditions, testing when solution is not known.
14	Simple Problems - VII	Wave equation. Physics, directional derivative. Solutions using characteristics. Solution by guessing.
15	Simple Problems - VIII	Numerical solution - FTCS. Stability analysis.
16	Simple Problems - IX	FTFS, FTBS, upwinding, CFL number, meaning, Application of boundary conditions. Physical conditions, numerical conditions.
17	Simple Problems - X	BTCS - stability analysis.
18	Simple Problems - XI	Stability analysis of the one - dimensional and two-dimensional heat equations. Connection to solution to Laplace's equation.
19	Simple Problems - XII	Modified equation. Consistency. Convergence. Stability.
20	Simple Problems - XIII	Effect of adding second order, third order fourth order terms to the closed form solution of the wave equation. Dispersion, dissipation.
21	Simple Problems - XIV	Demo - dissipation, dispersion.
22	Simple Problems - XV	Difference between central difference and backward difference. Addition of artificial dissipation to stabilise FTCS.
23	Simple Problems - XVI	Other schemes - using Taylor's series.
24	Simple Problems - XVI	Nonlinear wave equation. Non-smooth solution from smooth initial conditions, derivation of the equation as a

		conservation law. Jump condition - Rankine-Hugoniot relation, speed of the discontinuity.
25	Simple Problems - XVII	Finite volume method. Finding the flux.
26	Simple Problems - XVIII	Implicit scheme. Delta form, application of boundary conditions. LUAF.
27	One-D Flow I	Derivation of Governing equations. Explanation of the problem. Tentative application of FTCS.
28	One-D Flow II	Non conservative form. Not decoupled. A r u, p non-conservative. Is there a systematic way to diagonalise. Relation between the two non-conservative forms.
29	One-D Flow III	Eigenvalues of A'. Eigen vectors., Modal matrix.
30	One-D Flow IV	Stability analysis. Inferred condition. Upwinding. Addition of artificial viscosity.
31	One-D Flow V	Application of boundary conditions.
32	One-D Flow VI	Demo - solution to one-dimensional flow.
33	One-D Flow VII	Delta form. Application of boundary conditions. Solution technique.
34	One-D Flow VIII	Delta form: LU approximate factorization.
35	One-D Flow IX	Finite Volume method. Finding the flux. Roe's Average.
36	Multigrid - 1	Effect of grid size on convergence - why? Geometry. Data transfer two grid correction.
37	Multigrid - II	Multi- grid more than two grids, V-cycle, W - cycle., work units.
38	Multigrid - III	Demo + One – d Euler equation.
39	Calculus of Variations - I	Three lemmas and a theorem.
40	Calculus of Variations - II	Three lemmas and a theorem - problems, ode.

41	Calculus of Variations - III	Application to Laplace's equation.
42	Closure	Recap course.

References:

1. Elements of CFD. M. Ramakrishna.