

Pre-PhD COURSE
STABILITY ANALYSIS & SPECTRAL METHODS

Course Code: NMA757/NMA758

L-T-P-C: 3-1-0-4

Course Outcomes: On satisfying the requirements of the course and upon its successful completion, students will have knowledge/skills/competency to-

CO 1	explain the fundamental elements of fluid dynamics and derive governing equations of fluid flow in differential and integral forms.
CO 2	demonstrate the concept of flow stability and analyze hydrodynamic instabilities using linearized perturbation methods.
CO 3	apply stability theory to inviscid and viscous flows and solve related problems using appropriate stability equations and software tools.
CO 4	understand the fundamentals of spectral methods and compare them with traditional numerical techniques for solving differential equations.
CO 5	implement spectral methods, particularly Chebyshev-based techniques, for solving ODEs and PDEs in fluid flow problems.

UNIT-I

Basic Elements of Fluid Dynamics: Fluid and its properties, mass conservation in three dimensions, momentum and energy equation in three dimensions, equations of state, Navier–Stokes equations for a Newtonian fluid, conservative form of the governing equations of fluid flow, differential and integral forms of the general transport equations.

UNIT-II

Concept of stability: Reynold’s experiment on flow along a pipe, methods of hydrodynamic stability, bifurcation, instability, stability and the linearized problem, stability of the Poiseuille flow, physical description of instability, governing equations for perturbations, the linearized problem, Rayleigh-Taylor instability.

UNIT-III

Stability theory: Relevance and applications, linear inviscid stability analysis, Rayleigh stability equation, temporal and spatial stability analysis, convective and absolute instabilities, initial values problem, viscous stability analysis, Orr Sommerfeld and Squire’s equation, Capillary instabilities, Solve stability problems with suitable software.

UNIT-IV

Spectral Methods: Historical background, basic layout of spectral methods, spectral methods via orthogonal functions, spectral differential versus finite differences, types of spectral methods, fundamentals of spectral methods for ODEs and PDEs.

UNIT-V

Applications of Spectral Methods: Simple illustrations to solve ODEs and PDEs, Chebyshev spectral differential, successive linearization method, local linearization method, Chebyshev collocation method, Chebyshev Tau method.

Textbooks:

1. H. K. Versteeg, W Malalasekera, An Introduction to Computational Fluid Dynamics, Pearson Education Limited, 2007.
2. P. G. Drazin, Introduction to Hydrodynamic Stability, Cambridge University Press, 2002.
3. C. Canuto, A. Quarteroni, M. Y. Hussaini, T. A. Zang, Spectral Methods in Fluid Dynamics, Springer, 1988.

Reference Books:

1. L. N. Trefethen, Spectral methods in MATLAB, SIAM, 2000.
2. S. Chandrasekhar, Hydrodynamic and Hydromagnetic Stability, Dover Publications, 1981.