AE316 JAN 3:0

Hydrodynamic Stability

Instructor

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Teaching Assistant

None
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Department: Aerospace Engineering

Course Time: Tue, Thu, 10 - 11:30 AM

Lecture venue: AE 106

Detailed Course Page: https://samanta.coursesites.com/

Announcements

Brief description of the course

This course is designed for advanced graduate students in engineering and science with a definite interest to learn hydrodynamic stability. It assumes no background in the subject matter although some amount of familiarity may be helpful. However, strong fundamentals in fluid dynamics is a must along with good prior exposure in engineering mathematics or in a related course. Further, since a good fraction of the assignment problems would require the student to write their own codes, familiarity with a programming language and plotting package is needed. Mathematical modelling forms the core of this course, where all the required applied mathematics concepts are introduced during the regular lecture hours as required. Being the only course in this area at the Institute, this course stresses significantly in establishing the fundamentals, although significant exposure is provided with newer concepts and current state-of-the-art, designed in a way such that a serious student would be easily able to adapt it further toward the course of his/her research work, if required.

Prerequisites

1. A graduate level course in fluid dynamics or equivalent.

2. A graduate level course in engineering mathematics or equivalent.

Syllabus

Applied mathematics: analyticity of complex functions, classification of singular points, single-valued & multi-valued functions, branch cuts, Frobenius method, dispersion relations of waves: hyperbolic & dispersive, phase speed, group velocity, Chebyshev polynomials & their use in discretizations, solution of eigen problems, asymptotic theory, order symbols, asymptotic expansions, regular & singular perturbation methods, WKBJ method.

Introduction: historical notes, approaches, mathematical definitions, critical Re, instability mechanisms, basic steps in analysis.

Temporal, inviscid stability: linear stability equations (Rayleigh equation), inflection point theorem, Fjortoft's criterion, critical layers, Tollmien's inviscid solutions, solutions to piecewise linear profiles, Kelvin-Helmholtz instability.

Temporal, viscous stability: Orr-Sommerfeld & Squire's equations, Squire's transformation, numerical solutions, example of viscous stability of important flows, asymptotic solutions for large Re.

Spatial stability: issues & challenges, Orr-Sommerfeld & Squire's equations for spatial problems, Gaster's transformation, absolute & convective instability, non-parallel effects, method of multiple scales, parabolic equations, parabolized stability equations in two and three dimensions, extensions to include non-linear terms, global methods.

Non-modal analysis: motivation, temporal initial-value problem, optimal growth & response, spatial problem.

Special topics: thermal instability (Rayleigh-Benard problem) and interface instability due to density mismatch (Rayleigh-Taylor instability); methods in absolute instability; introduction to secondary instability; stability of boundary layers and transition.

Course outcomes

During the course, students would learn the fundamental theory behind hydrodynamic stability along with a selection of the latest concepts. At the end of this course, they would obtain hands-on experience in developing the necessary theory to analyse a new flow problem. Further, they would know how to solve such problems using applied mathematics concepts or, instead, numerically via developing a series of codes for hydrodynamic stability problems during the coursework.

Grading policy

Homeworks: 30%

Term Paper: 20% for Presentation

& 10% for Report

Final exam: 40%

Assignments

Four to five assignment sets are expected to be assigned during the term. Most of the problems will require theoretical deductions and/or computer programming. A knowledge of any computer programming language or software (e.g. MATLAB) is essential.

Resources