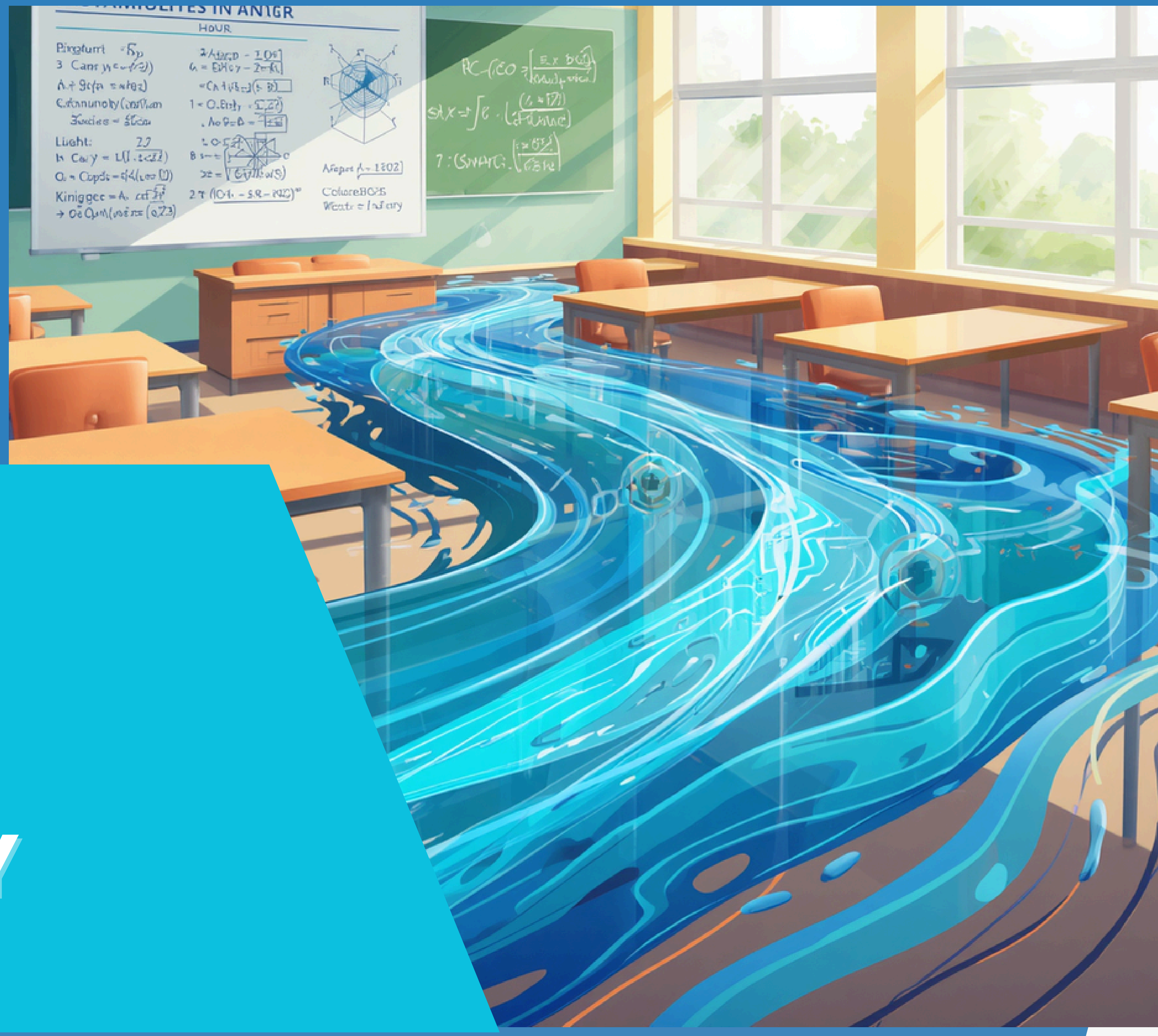
Politecnico di Torino
Dipartimento di Ingegneria Meccanica e Aerospaziale



PH.D. IN AEROSPACE ENGINEERING
PHD COURSE - INVITED LECTURES

INTRODUCTION TO HYDRODYNAMIC STABILITY

SPEAKER

FLAVIO GIANNETTI
Università degli Studi di Salerno

Wednesday July 8, 09:00 – 12:30
Thursday July 9, 09:00 – 12:30
Friday July 10, 09:00 – 12:30

Sala Ferrari, II floor, DIMEAS - Politecnico di Torino

Abstract
This course introduces the fundamental principles and analytical techniques of instability theory as applied to fluid mechanics. The course examines several canonical types of flow instabilities, elucidating the underlying physical mechanisms governing their development.
Linear stability analysis is formulated through the method of normal modes, with particular emphasis on local instability characteristics—including temporal, spatial, and spatio-temporal growth—in parallel base flows, illustrated through the example of a free shear layer and boundary layers. The concepts of transient growth and optimal perturbations are introduced and analysed for Poiseuille flow.
The distinction between convective and absolute instability is discussed, highlighting the physical interpretation of wave packet evolution and its implications for the onset of self-sustained oscillations in open flows.
The stability of non-parallel steady flows, such as the cylinder wake, is subsequently characterized through global eigenmode analysis, linking local instability features to the emergence of global oscillatory behaviour. The concept of Structural Sensitivity is presented and discussed to analyse localization. Theoretical lectures are complemented by integrated exercise sessions, in which students will use MATLAB/Python together with FreeFem++ on their own computers to gain numerical and computational experience with the theoretical concepts presented in class.
Assessment is based on a final group project.

Program Outline
1. Introduction to Dynamical Systems (1 h)
Classification of fixed points and bifurcations. Basic concepts of stability and transition to instabilitynb in low-dimensional systems.
2. Governing Equations and Linearization (1 h)
Review of the Navier–Stokes equations and their linearization about a base flow. Perturbation formulation and energy considerations.
3. Asymptotic Stability and Normal Mode Analysis (2 h)
Definition of asymptotic stability; derivation and interpretation of normal modes. Introduction to numerical methods for eigenvalue problems in hydrodynamic stability.
4. Stability of Parallel and Quasi-Parallel Flows (2 h)
Analysis of shear flows and boundary-layer flows. Inviscid and viscous instability mechanisms.
5. Non-Modal Stability and Transient Growth (1 h)
Non-normal operators, transient energy amplification, and example of Poiseuille flow.
6. Types of Instabilities: Spatial and Spatio-Temporal Frameworks (2 h)
Spatial versus spatio-temporal stability theory. Convective and absolute instabilities; criteria for distinguishing instability types and their physical implications.
7. Global Stability and Structural Sensitivity (1 h)
Stability of non-parallel flows and global mode analysis. Connections to weakly non-parallel concepts. Structural sensitivity, mode localization, and examples of short- and long-range instabilities.