Ph.D. programme in Civil Systems Engineering

Environment fluid mechanics and hydraulics – Part I

Prof. Andrea Vacca

Credits: 3 CFU
Number of hours: 24 frontal hours
Data: October 2025, November 2025

Objectives:
The course will provide an introduction to the problem of the fluid dynamic transition and turbulence.

Course programme:
Different themes will be approached though a set of invited lectures that deal with:

- Transition: problem of the hydrodynamic stability.
- Transition: normal mode analysis.
- Transition: Squire theorem. Orr-Sommerfield equation.
- Turbulence: Reynolds averaged equations (RANS).
- Turbulence: budgets of mean and turbulent kinetic energy.
- Turbulence: energy cascade process. Komogorov theory.
- Turbulence: RANS models with zero, one and two equations.

Assessment methods: Final interview

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Lectures Program

N	Date	Schedule	Duration	Teacher	Topic
1	25/09/25	14:00 - 16:00	2 hours	A. Vacca	Course Introduction.
2	01/10/25	09:30 - 12:30	3 hours	B. Vacca	Review of fluid mechanics: conservation equations of mass and momentum, both in differential and integral form
3	02/10/25	14:30 - 17:30	3 hours	Vacca	Flow between two parallel plates: laminar case. Velocity profile and resistance coefficient. Kinetic energy

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					balance: differential and integral form. Physical interpretation of the various terms
4	08/10/25	09:30 - 12:30	3 hours	Vacca	Stability and transition to turbulence. Normal mode analysis: inviscid case. Three-dimensional and two-dimensional disturbances. Squire transformation and related theorem
5	09/10/25	14:30 - 17:30	3 hours	Vacca	Normal mode analysis: inviscid case. Rayleigh's criterion. Normal mode analysis: viscous case. Two- and three-dimensional disturbances. Squire transformation and related theorem. Two-dimensional stability curve: discussion
6	15/10/25	09:30 - 12:30	3 hours	Vacca	Orr–Sommerfeld equations. Turbulence: Reynolds decomposition and derivation of the RANS equations
7	16/10/25	14:30 - 17:30	3 hours	Vacca	Mean kinetic energy balance equation. Reynolds stress balance equation and turbulent kinetic energy
8	22/10/25	09:30 - 12:30	3 hours	Vacca	Elements of Kolmogorov's theory. Turbulent flow between two parallel plates. Discussion of turbulent shear stress. Velocity profile: viscous layer, inner layer, wake

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