2025/2026 FLUIDODINAMICA GEOFISICA

FISICA [SM23] Laurea Magistrale - Fisica dei sistemi complessi, clima e finanza
SSD: ICAR/01, GEO/12
24 hours, 6 CFU
Lecturers: Riccardo Farneti (rfarneti@ictp.it), Stefano Salon (ssalon@inogs.it)

Aims: To introduce students to fluid dynamics basic principles and to the main topics of geophysical fluid dynamics

Syllabus

Part I Fluid Mechanics

Lecture 1 Introduction to Fluid Mechanics: Properties and definition; Viscosity; Statics; Pressure and Buoyancy force
Lecture 2 Tensors; Gradient, Divergence, Curl; Stokes and Gauss Theorems; Lagrangian Derivative and Streamlines
Lecture 3 Kinematics: Strain rates; Vorticity and Circulation; Streamfunctions; Relative motion near a point
Lecture 4 Conservation of Mass: Reynolds Transport Theorem; Continuity, Advection-Diffusion Equation
Lecture 5 Conservation of Momentum: Cauchy's Equation; Constitutive equation for Newtonian fluids
Lecture 6 Conservation of Momentum: Navier-Stokes Equations
Lecture 7 Conservation of Momentum: Rotating frame of reference and Coriolis
Lecture 8 Conservation of Energy: Mechanical energy; Thermal energy equation
Lecture 9 Conservation of Energy: Bernoulli equation
Lecture 10 Vorticity dynamics

Part II Geophysical Fluid Dynamics

Lecture 10 Introduction to Geophysical FD: scales of motion, rotation/stratification in atmosphere and ocean
Lecture 11 Rotating frame of reference: Coriolis force, inertial oscillations, acceleration on a 3-D rotating planet
Lecture 12 Governing equations of GFD: momentum, mass conservation, energy, equation of state
Lecture 13 Boussinesq approximation; scale analysis and further simplifications of governing equations; Rossby, Ekman, Reynolds numbers
Lecture 14 Geostrophy: geostrophic flows; Taylor-Proudman theorem; non-geostrophic flows; vorticity dynamics
Lecture 15 Friction and rotation 1: Prandtl hypothesis, Bottom Ekman layers
Lecture 16 Friction and rotation 2: Surface Ekman layer, Ekman pumping, Ekman layers in real geophysical flows
Lecture 17 Barotropic waves 1: hypotheses, Kelvin waves, Poincarè waves
Lecture 18 Barotropic waves 2: Rossby waves, topographic waves and their analogies
Lecture 19 Stratification: static stability, Froude number, combination of rotation and stratification
Lecture 20 Mixing 1: mixing of stratified fluids, Kelvin-Helmoltz instability – Instability of a stratified shear flow
Lecture 21 Mixing 2: Taylor-Goldstein equation, Richardson number; turbulence in a stratified shear flow

Books: any textbook on Fluid Mechanics / GFD, but particularly:

- `Introduction to Geophysical Fluid Dynamics - Physical and Numerical Aspects' by B. Cushman-Roisin J.-M. Beckers (https://www.elsevier.com/books/introduction-to-geophysical-fluid-dynamics/cushman-roisin/978-0-12-088759-0) (http://www.ccpo.odu.edu/~klinck/Reprints/PDF/roisinGFD2010.pdf)
- `Physical Fluid Dynamics' by D. J. Tritton
- `Fluid Mechanics' by P. K. Kundu (available online)
- `Atmospheric and Oceanic Fluid Dynamics' by G.K. Vallis
- `Essentials of Atmospheric and Oceanic Dynamics', by G.K. Vallis