Turbulence and Mixing

Subject area: Physics

University:	TalTech
Level:	MA all years, PhD
Teaching mode:	hybrid: some students participate online, other students attend real-life
Instructor(s):	Jaan Kalda

Short description

The course gives an overview of the theory of turbulence with focus on qualitative undrestanding.
Keywords: strong and weak turbulence; Navier-Stokes equation; vorticity; diffusion; advection; Reynolds, Scmidt,Prandtl, Kubo and Peclet numbers; Kolmogorov turbulence; forward and inverse cascades; Richardson's law; Batchelor's law; intermittency; structure functions; statistics of material elements; Lyapunov exponents; compressible advection; particles in turbulence; warm clouds; magnetic dynamo.

Full description

The following topics will be studied.
Classification of turbulence: weak turbulence - turbulence with weakly nonlinear random wave-like solutions, analytical studies based on perturbation theories; strong turbulence - turbulence with coherent structures (vortices, solitons etc), in media which do not support linear solutions or where the energy density is so high that perturbation theories cannot be used.
Navier-Stokes equation and its simplified inviscid form - the Euler equation. Integrals of motion of the Euler equation: vorticity, and infinite number of integrals of motion in the two-dimensional case. Using these integrals of motion to show stability of 2-dimensional cylindrical vortices. Dissipative instability.
Two approaches to advective diffusion: via Brownian motion of an ensemble of particles, and via convective-diffusive equation.
Sub- and superdiffusion; fractional diffusion equation.
Dimensionless numbers: Reynolds, Schmidt, Prandtl, Kubo and Peclet numbers. Vast number of qualitatively different advective diffusion processes corresponding to different values of these numbers.
Percolation-theory-approach to study the advective diffusion at the limit of large Peclet and Kubo numbers.
Kraichnan model of delta-correlated flows and why it works fairly well in modelling real time-correlated flows.
Kolmogorov turbulence and power laws. Forward and reverse cascade. Formation of cyclones and anticyclones.
Richardson's law for pair dispersion of particles in hydrodynamic turbulence. Batchelor's law for the power spectrum of passive scalars in chaotic flows.

Intermittency and structure functions - for turbulent velocity fields and for passive scalar fields.
Anomalous scaling of structure functions.
Lagrangean statistics of material elements (material lines and volumes) and Lyapunov exponents.
Compressible velocity fields: strongly and weakly compressible flows.
Particles in turbulence: the effect of inertia and drag, clustering of particles.
Nucleation of droplets in warm clouds: the diffusive growth bottleneck, the sling effect.
Magnetohydrodynamics and electron magnetohydrodynamics: conservation of magnetic flux through material loops, transport of magnetic fields. The problem of magnetic dynamo: stretch-twist-fold action and the creation of cosmic magnetic fields.

Learning outcomes

Knows the basic models, methods and results of the theory of turbulence,
and is able to use these in his/her professional work.

General information

Contact hours per week:	4
Total workload:	156 (in student hours for the whole course)
ECTS credits:	6
Language:	English
Course start date:	22 August 2022
Course end date:	22 January 2023
Add. info about start date:	
Weekly teaching day/time:	
Time zone:	CET +1 (Estonia, Israel)
Further information:	
Prerequisites:	-
Activities and methods:	Lectures, Seminars, Self-study, Exercises
Presence on campus:	no presence needed

Final examination

Form:	assignment
Date:	
Location/format:	online

Re-sit possibility:	yes
Transcript available:	end of semester
Add. info/requirements:	

Registration

To register for this course, follow the registration requirements of your **home university** as specified here: www.euroteq.eu/courses-registration.

Administration

Number of places:	
Minimum participants:	
Internal course code:	YFX1100
Contact:	kalda@ioc.ee

This course is part of the EuroTeQ Engineering University joint course catalogue 2022/2023. This is a collaborative activity of the partner universities DTU, L'X, TU/e, TalTech, CTU, TUM as well as Technion. Students from these universities can participate in the offered courses. It is the responsibility of the student to check if you fulfil the requirements to participate in a specific course. Students are also advised to check with their home institution how to get recognition of the ECTS credits gained in courses of the EuroTeQ course catalogue. For further information about EuroTeQ Engineering University, visit www.euroteq.eu or get in touch with the above-mentioned point of contact.