MECA2853 Turbulence.

[30h+15h exercises] 4 credits

This course is taught in the 1st semester

Teacher(s): Guy Schayes, Grégoire Winckelmans
Language: French
Level: Second cycle

Aims

- Develop a detailed theory of turbulence
- Present existing models and their limitations.
- Apply the theory developed to various phenomenom in fluid mechanics, in engineering and in geophysics.
- Present an introduction to the numerical simulation of turbulent flows.

Main themes

Starting from generalities on turbulence theory (problematics, isotropic turbulence, wall-bounded turbulence, basic models), the course will present a detailed analysis of turbulence physics for diverse classes of applications (industrial flows, aerodynamics, atmosphere, oceans). The principal methods of numerical simulation (RANS and LES) will be presented.

Content and teaching methods

1.Généralities
Trubulent flows, physics and characteristics of turbulence, unsteady aspects.
Reynolds averages (temporal averages, ensemble averages), conservation equations for the mean fields, Reynolds stresse and fluxes: turbulent transfers (momentum, heat).
Conservation equations for the turbulent kinetic energy and for the energy of the mean field.
Boussinesq approximation: linear model of effective turbulence viscosity and of effective turbulence conductivity, turbulent Prandtl number, Reynolds analogy.
2.Wall-bounded turbulence
Flow description, turbulent boundary layers: length and velocity scales, mixing length, effective turbulence viscosity.
Internal zone (near wall) and external zone (away from wall), laminar sublayer, inertial zone, logarithmic law, friction coefficient.
Pipe and channel flows: head losses coefficient, effect of wall rougnesss.
3.Isotropic turbulence
Scales of turbulence, energy cascade, Fourier analysis and energy spectrum, Kolmogorov theory, effects of production and of dissipation, velocity correlation functions, structure functions, comparison with experiments.
4.Free shear flows: jets and shear layers, coherent structures in turbulence
Phenomenological description and visualisation, experimental results and numerical simulations (growth rate, effective stresses and effective turbulence viscosity, coherent structures), similarity analysis and similarity profiles.
5.Stratification effects
Turbulence in presence of volume forces (stratification).
Geohydrodynamic equations, Ekman layers, energetics of turbulence in a stratified medium (stable or unstable), atmospheric and oceanic boundary layers.
Environmental problems.
6.Natural convection
Thermal effects in turbulence
Scales in natural convection, Boussinesq approximation, conservation of energy.
atmospheric and oceanic convection.
7.Reynolds approach
RANS approach ("Reynolds Averaged Navier-Stokes" models), closure of the models.
Classical effective viscosity models (mixing length, k-e, etc.).
Stratification effects, Mellor-Yamada model.
Secondary flows, non-linear k-e model, Reynolds stress models. Boundary conditions, numerical issues.
8.Large eddy simulation (LES) approach
Projections and filters, resolved scales and subgrid scales, spectrum.
Conservation equations, effective stresses due to projection and/or filtering.
Smagorinsky model.
Recent developments and models
Numerical issues.
9.Initiation to two-dimensional turbulence
Atmospheric and oceanic variability, general circulation and meso-scale vortices, baroclinic instability, oceanic currents, Gulf Stream.
Turbulence in conducting flows, in presence of magnetic fields.

Other information (prerequisite, evaluation (assessment methods), course materials recommended readings, ...)

Prerequisite :
- Continuum mechanics
- Fluid mechanics
- Basic knowledge of turbulence and its theory
- Elements of numerical simulation

NB: Appropriate references will be provided to the students without sufficient formation in the last two domains

Programmes in which this activity is taught

MAP2 Ingénieur civil en mathématiques appliquées

Other credits in programs

MAP23	Troisième année du programme conduisant au grade d'ingénieur civil en mathématiques appliquées	(4 credits)	
MECA23	Troisième année du programme conduisant au grade d'ingénieur civil mécanicien	(4 credits)	
PHYS22/G	Deuxième licence en sciences physiques	(4 credits)	
PHYS22/T	Deuxième licence en sciences physiques (Physique de la terre, de l'espace et du climat)	(4 credits)	Mandatory