UCL Université catholique de Louvain

LMECA2853

2013-2014

Turbulence.

5.0 credits	30.0 h + 30.0 h	1q

Teacher(s) :	Winckelmans Grégoire ; Deleersnijder Eric ;
Language :	Français
Place of the course	Louvain-la-Neuve
Inline resources:	> http://icampus.uclouvain.be/claroline/course/index.php?cid=MECA2853
Prerequisites :	-- Continuum mechanics -- Fluid mechanics -- Elements of turbulence theory -- Elements of numerical simulation NB: Appropriate references will be provided to the students without sufficient formation in the last two domains
Main themes :	Starting from generalities on turbulence theory (problematics, averaged equations and basic models, wall-bounded turbulence), the course will present a detailed analysis of turbulence physics (homogeneous isotropic turbulence, free shear flows) as well as diverse classes of applications (industrial flows, aerodynamics, geophysical and environmental flows). The principal methods of numerical simulation (RANS and LES) will also be presented.
Aims :	After this course, the student will be able to: -- 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. *The contribution of this Teaching Unit to the development and command of the skills and learning outcomes of the programme(s) can be accessed at the end of this sheet, in the section entitled "Programmes/courses offering this Teaching Unit".*
Evaluation methods :	Project and written exam (possibly oral discussion on the project or on one prepared question)
Teaching methods :	Courses and some other meetings (exercises, project)
Content :	1.Généralities Turbulent flows, physics and characteristics of turbulence, unsteady aspects. Reynolds averages (temporal averages, ensemble averages), conservation equations for the mean fields, Reynolds stresses and fluxes: turbulent transfers (momentum, heat). Conservation equations for the turbulent kinetic energy and for the energy of the mean field. Linear model of effective turbulence viscosity and conductivity (turbulent Prandtl number), Reynolds analogy. 1. 2. Wall-bounded turbulence: 2. Flow description, turbulent boundary layer: length and velocity scales, mixing length, effective turbulence viscosity. Inner zone (near wall) and outer zone (away from wall), laminar sub-layer, inertial zone, logarithmic law, friction coefficient. Pipe and channel flows: head losses coefficient. Effects of wall roughness. 3. 3. Homogeneous isotropic turbulence (HIT): 4. Scales of turbulence, Fourier analysis, energy spectrum, dissipation spectrum, energy cascade, Kolmogorov theory, Pao model spectrum, structure functions, two-points correlations, comparisons with experiments. 5. 4. Free shear flows: jets and shear layers: 6. Phenomenological description and visualization, coherent structures in turbulence, experimental and numerical simulation results (growth rate, effective turbulence viscosity), similarity analysis and similarity profiles. 7. 5. Stratification effects: 8. Turbulence in presence of volume forces. Geohydrodynamic equations, Ekman layers, energetics of turbulence in a stratified medium (stable or unstable), atmospheric and oceanic boundary layers. Environmental problems.

	9. 6. Natural convection: 10. Thermal effects in turbulence. Scales in natural convection, Boussinesq approximation, conservation of energy. Atmospheric and oceanic convection. 11. 7. Reynolds-averaged approach (RANS, Reynolds Averaged Navier-Stokes): 12. Averaged conservation equations and classical effective viscosity models. Closure using one or two equations (mixing length model, k-epsilon model, k-omega model). Calibration (using HIT and wall-bounded turbulence). Stratification effects, Mellor-Yamada model. Secondary flows, Non-linear k-epsilon model for capture of secondary flows. Boundary conditions. 13. 14. 8. Large eddy simulation (LES) approach: 15. Truncation of physical scales and thus of the spectrum, resolved scales and subgrid scales. Truncated conservation equations and effective subgrid-scales stresses. Smagorinsky model. Recent developments and multiscale models. Numerical issues. Examples of applications. 9. Atmospheric and oceanic variability, general circulation and meso-scale vortices
Bibliography :	-- Tennekes H. and Lumley J.L., A First Course in Turbulence, The MIT Press, 1972 -- Pope S.B., Turbulent Flows, Cambridge University Press -- Burchard H., Applied Turbulence Modelling in Marine Water, Springer Verlag -- Cushman-Roisin B. and J.-M. Beckers, 2011 (2nd ed.), Introduction to Geophysical Fluid Dynamics, Academic Press -- Slides and complementary documents, on iCampus
Cycle and year of study :	> Master [120] in Physics > Master [120] in Mechanical Engineering
Faculty or entity in charge:	MECA