UCLouvain

# lmeca2853

*2018*

# Turbulence.

| 5 credits | 30.0 h + 30.0 h | Q1 |
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| Teacher(s) | Deleersnijder Eric ;Winckelmans Grégoire ; |
| Language : | English |
| Place of the course | Louvain-la-Neuve |
| Main themes | Starting from generalities on turbulence (problematics, turbulent channel flow or pipe flows, turbulent boundary layers, basic models), the course will present a detailed analysis of turbulence physics for diverse classes of canonical flows (homogeneous isotropic turbulence, free shear flows, wall-bounded shear flows). The principal methods of numerical simulation (RANS and LES) will be presented. Diverse applications will be considered (industrial flows, aerodynamics, atmosphere, oceans). |
| Aims | 1 In consideration of the reference table AA of the program "Masters degree in Mechanical Engineering", this course contributes to the development, to the acquisition and to the evaluation of the following experiences of learning:<br>• AA1.1, AA1.2, AA1.3<br>• AA2.1, AA2.4, AA2.5<br>• AA3.1, AA3.3<br>• AA4.1, AA4.2, AA4.3, AA4.4<br>• AA5.4, AA5.5, AA5.6<br>• AA6.1, AA6.3<br>The student will be able to:<br>• Present a detailed theory of turbulence for canonical cases (homogeneous isotropic turbulence, free shear flows, wall-bounded shear flows,).<br>• Present existing models and appreciate their limitations.<br>• Apply the theory developed to various phenomena in fluid mechanics, in engineering and in geophysical and environmental fluid flows (atmosphere, oceans, estuaries, etc.).<br>• Present an introduction to the numerical simulation of turbulent flows (RANS and LES).<br>- - - -<br>*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 | Continuous assessment of knowledge and/or project, and written exam (possibly oral discussion on the project or on one prepared question) |
| Teaching methods | Typically 13 courses (26 hours) and a project. Also possibly some tutored exercices and/or a homework. |
| Content | **Introduction and generalities**: Turbulent flows, physics and characteristics of turbulence. Reynolds averages (temporal averages, ensemble averages), conservation equations for the mean fields, Reynolds stresses and fluxes: turbulent transfer or momentum, heat, mass. Linear models of effective turbulence viscosity and conductivity.<br>**Turbulent shear flows with walls**: Turbulent channel flows or pipe flows, turbulent boundary layers, characteristic lengths, friction velocity, friction-conduction temperature, turbulence effective viscosity and conductivity. Profiles: inner zone (near wall) including a laminar sub-layer, buffer zone with logarithmic profile (von Karman), outer zone with composite profile (Coles). Effect of wall roughness.<br>**Homogeneous isotropic turbulence (HIT)**: Large scales, inertial scales and small scales (Kolmogorov scale), spectral analysis, energy spectrum, energy cascade, Kolmogorov theory, Pao model spectrum, structure functions, two-points correlations, Taylor micro-scales. Numerical simulation of HIT, and comparison with theory and with experimental results.<br>**Turbulent free shear flows**: jets and shear layers: Phenomenological description and visualization, coherent structures in turbulence, experimental and numerical simulation results (growth rate, effective turbulence viscosity), similarity analysis and similarity profiles.<br>**Rotation and stratification effects**: Turbulence in the presence of volume forces. Atmospheric and oceanic variability, geohydrodynamic equations, Ekman layers, energetics of turbulence in a stratified medium (stable or unstable), atmospheric and oceanic boundary layers. Environmental problems.<br>**Natural convection**: Thermal effects in turbulence. Scales in natural convection, Boussinesq approximation, conservation of energy. Atmospheric and oceanic convection.<br>**Reynolds-averaged approach**(RANS, Reynolds Averaged Navier-Stokes equations): Conservation equations for the averaged fields and classical effective viscosity and conductivity models. Equation for the turbulent kinetic |

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| | energy, k. Closure using one or two equations (mixing length model, k-epsilon model, k-omega model). Calibration (using HIT and wall-bounded turbulence). Stratification effect, and Mellor-Yamada model. Boundary conditions.<br>**Large eddy simulation (LES) approach**: Truncation of physical scales and thus of the spectrum, resolved scales and subgrid scales. Truncated conservation equations and effective subgrid-scales stresses and heat fluxes. Smagorinsky model and his calibration in HIT. Recent developments and multiscale models. LES of wall-bounded flows. Examples of applications. LES with explicit filtering added to the truncation (filtered and truncated fields). |
| Inline resources | http://moodleucl.uclouvain.be/enrol/index.php?id=5583 |
| Bibliography | • Lecture notes, slides and computer animations available on Moodle<br><br>• Tennekes H. and Lumley J. L., A First Course in Turbulence, The MIT Press, 1972<br>• Pope S. B., Turbulent Flows, Cambridge University Press (**conseillé**)<br>• Burchard H., Applied Turbulence Modelling in Marine Water, Springer Verlag<br>• Cushman-Roisin B. and J.-M. Beckers, Introduction to Geophysical Fluid Dynamics, Academic Press, 2011<br>• Transparents et documentation/notes complémentaires des titulaires. |
| Faculty or entity in charge | MECA |

| Programmes containing this learning unit (UE) | | | | |
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| Program title | Acronym | Credits | Prerequisite | Aims |
| Master [120] in Electro-mechanical Engineering | ELME2M | 5 | | |
| Master [120] in Mechanical Engineering | MECA2M | 5 | | |
| Master [120] in Civil Engineering | GCE2M | 5 | | |
| Master [120] in Physics | PHYS2M | 5 | | |