UCLouvain

lmeca2322

2024

Fluid mechanics II

5.00 credits	30.0 h + 30.0 h	Q1

Teacher(s)	Chatelain Philippe ;Deleersnijder Eric ;Winckelmans Grégoire ;
Language :	English > French-friendly
Place of the course	Louvain-la-Neuve
Prerequisites	Mécanique des fluides et transferts 1 [lmeca1321] or equivalent
Main themes	• Compressible flows in ducts and nozzles • Incompressible flows in porous media • Potential flows • Introduction to transition, turbulence, and CFD • Introduction to geophysical and environmental flows
Learning outcomes	**At the end of this learning unit, the student is able to :** In view of the LO frame of reference of the "Master Mechanical Engineering", this course contributes to the development, acquisition and evaluation of the following learning outcomes: LO1.1, LO1.2, LO1.3 LO2.1, LO2.2, LO2.3, LO2.4, LO2.5 LO3.1, LO3.2 LO4.1, LO4.2, LO4.3, LO4.4 LO5.4, LO5.5, LO5.6 LO6.1, LO6.2 **Specific learning outcomes of the course** At the end of this learning unit, the student will be able to: 1 • Use the concepts and the associated equations of the simplified 1-D view, for compressible flows in ducts with friction, and in nozzles without friction, for various boundary conditions (reservoir and outlet); the acquisition and manipulations of the concept and equations being also supported by an experimental laboratory. • Apply the theory on flows in a porous media to various cases, linear and non-linear; also decide when non-linearity must be taken into account. • Manipulate the simple tools of 2-D potential flow theory to analyze various flows; also the flow past a circle and past an airfoil profile (obtained by transformation of a circle). Draw, using streamlines, flows with and without circulation, and exercise a critical view on the result, based on physics. • Comprehend the basic assumption of linear stability theory, the corresponding equations, and their application to the examples presented in class. Solve the equations in simple cases (e.g., for a piecewise linear flow). Comprehend the phenomenological description of the transition to turbulence. • Distinguish between the various scales of developed turbulence, also in terms of the energy spectrum (inertial range, dissipation range). Appreciate the impact on resolving scales in turbulent flows. • Comprehend the Reynolds averaging approach, also for shear flow, and the simple closure models of the RANS equations. • Use critical thinking when using a CFD software to compute a RANS solution of a case with medium geometrical complexity, also as supported by the Best Practice Guidelines (mesh quality, etc.). • Comprehend the specific dynamics of turbulent and stratified flows in a rotating reference frame, with specific applications to environmental and geophysical problems, thus enabling the students capable of engaging with researchers, practitioners and relevant officials.

Evaluation methods	The laboratory session(s) and the homework correspond to work that is mandatory and that must be performed during the quadrimester; each within a well-defined time period and with a given deadline for the report, that is graded. It is mandatory to participate physically in each laboratory session. No experimental laboratory report will be accepted with the name of a student who did not participate in the laboratory. It is not possible to do, or even re-do, any of the work mentioned above outside of the time period that was defined for it within the quadrimester. The final exam is a written exam, with questions that can cover all parts of the course (lectures, exercice and laboratory sessions, homework). The calculation of the final grade obtained by the student for the course is a weighted sum of the grade obtained for the final written exam (for 75 %) and of the grade obtained for the work to be performed during the quadrimester (laboratories and homeworks, for 25 %). It is however required to obtain at least 8/20 at the exam for that rule to apply. If the grade obtained at the exam is below 8/20, the final grade for the course is the grade of the exam. If the student does not obtain the credit for the class at the deliberation of June, the grade obtained for the work to be performed during the quadrimester remains acquired for the second session of August.
Teaching methods	There are lectures given in an auditorium, each of 2 hours. The student must also acquire some of the course content on his/her own (e.g., content that is a review of material covered in previous mandatory courses, mathematical developments not covered in class). Sessions of practical exercices (TP) are also organised in class, each of 2 hours and with an assistant, to further develop/detail the concepts covered during the lectures, and to do applications. Some sessions are not organised in class. There are also laboratory sessions led by an assistant: a laboratory on supersonic nozzle flow in groups of 5-6 sudents and with one group report, and a laboratory on introduction to CFD in groups of 3 students and with one report). There are also homeworks. The use of generative AI tools such as ChatGPT, Consensus, Perplexity,... to produce parts of results or reports is not allowed.
Content	Complements on turbulence, and introduction to CFD • Recall of previous material (from lmeca1321): Reynolds-Averaged Navier-Stokes (RANS) equations; also simplified for thin shear flows, such as boundary layers. • Closure of the RANS equations using a turbulent viscosity model: two-equations closure models. Calibration of the model coefficients • Hands-on session using a CFD solver, and best practice guidelines. • Scales in turbulent flows. Simple case of decaying homogeneous isotropic turbulence (DHT) in a periodic box: energy spectrum (Kolmogorov) and spectrum models. Experimental approximation of DHIT in a wind/water tunnel. Introduction to geophysical and environmental flows (loosely inspired by the concept of sustainable development) • Time and space scales of variability. • Reactive transport. • Geohydrodynamic equations. • Impact of Earth's rotation and stratification. • Relevant case studies (e.g., contaminant dispersion, geostrophic equilibrium, Ekman boundary layer). Compressible flows in ducts and nozzles • Recall of the conservation equations for compressible flows (mass, momentum, energy). Conservation equation for the entropy. • Link between isentropic flows at moderate Mach number and ideal incompressible flows. • 1-D isentropic flow in a converging-diverging Laval nozzle (subsonic and supersonic cases), sonic conditions and maximum flow rate. Normal shock in a supersonic flow and jump relations. Operating modes of a nozzle. • 1-D adiabatic flow in a duct with wall friction (Fanno flow). 2-D potential flows (incompressible and irrotational) • Basic singularities: point vortex, point source/sink, dipole. • Obtention of flows using complex potentials. • Flow past a circle: case without circulation and case with circulation (Magnus effect). • Transformation of a circle into airfoils of various shapes (Joukowski transformation). • Flow past airfoils of various shapes. Kutta-Joukowski condition. • Blasius formula to compute the force acting on the body. Lift due to the circulation.
Inline resources	Moodle site of the course

Bibliography	**Non-exhaustive list:** G.K. Batchelor, *An Introduction to Fluid Dynamics*, Cambridge University Press 1967 (reprinted paperback 1994). F. M. White, *Viscous Fluid Flow*, second edition, Series in Mechanical Engineering, McGraw-Hill, Inc., 1991. P. A. Thompson, *Compressible Fluid Dynamics*, advanced engineering series, Maple Press, 1984. D.J. Tritton, *Physical Fluid Dynamics*, Van Nostrand Reinhold, UK, 1985. P. G. Drazin, *Introduction to Hydrodynamic Stability*, Cambridge Texts in Applied Mathematics, Cambridge University Press, 2002 P. G. Drazin and W. H. Reid, *Hydrodynamic Stability*, Cambridge University Press, 1985. S. B. Pope, *Turbulent Flows*, Cambridge University Press, 2000 M. Van Dyke, *An Album of Fluid Motion*, The Parabolic Press, 1982. H. Burchard, *Applied Turbulence Modelling in Marine Waters*, Springer, 2002 B. Cushman-Roisin and J.-M. Beckers, *Introduction to Geophysical Fluid Dynamics - Physical and Numerical Aspects*, Elsevier, 2011 (2nd ed.) H. B. Fisher et al., *Mixing in Inland and Coastal Waters*, Academic Press, 1979 P. Kundu et al., *Fluid Mechanics*, Elsevier, 2015 (6th ed.)
Faculty or entity in charge	MECA

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Learning outcomes
Master [120] in Mechanical Engineering	MECA2M	5		
Master [120] in Electro-mechanical Engineering	ELME2M	5		
Master [120] in Energy Engineering	NRGY2M	5		