UCLouvain

lmeca2322

2021

Fluid mechanics II

5.00 credits	30.0 h + 30.0 h	Q1

Teacher(s)	Chatelain Philippe ;Deleersnijder Eric ;Winckelmans Grégoire ;
Language :	English
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 homeworks and the laboratory correspond to work that is mandatory and to be performed during the quadrimester; each within a given time slot and with a given deadline for the report (which is graded). The final note of each student takes into account the notes obtained for the work performed during the quadrimester (homeworks and laboratory) and the note obtained at the final written exam.

Teaching methods	There are typically 13 lectures in class, each of 2 hours. The student must also acquire some of the course content on their own (e.g., content that is essentially 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, to further develop concepts covered during the lectures and to do some applications. Some session are not organised in class (e.g., practice session using a CFD software, laboratory). The students must also perform a number of homeworks (typically 3). These homeworks are mandatory and they must be done during the quadrimester, each with a start date and a deadline date for the report, which is graded. Depending on the amplitude of the work/effort expected, these homeworks are done alone or in team of two. The students must also participate to the laboratory on compressible flows that is organised in small groups; each group must produce one laboratory report, which is also graded.
Content	Compressible flows in ducts and nozzles • Recall of the conservation equations (mass, momentum, energy). • Link between isentropic flows at moderate Mach number and ideal incompressible flows. • 1-D isentropic flow in a converging-diverging Laval nozzle (subsonic, supersonic), sonic conditions and maximum flow rate. Normal shock and jump relations. Operating modes of a nozzle. • 1-D flow in a duct with wall friction (Fanno). Incompressible flows in porous media • Linear case and model (Darcy). • Extended model for nonlinear case with some inertial effects. • Examples of applications (e.g., in rock physics, etc.). Potential flows • Point vortex, point source/sink, dipole. • Obtention of flows using a complex potential. • Flow past a circle: case without circulation; case with circulation and associated lift (Magnus effect) . • Flow past an airfoil and associated lift. Introduction to transition, turbulence, and CFD • Linear stability theory, and examples of application. • Phenomenology of the transition to turbulence. • Scales in developed turbulence: energy spectrum and dissipation (Kolmogorov). • Reynolds-Averaged Navier-Stokes (RANS) equations; also simplified for shear flows (boundary layer, jet, wake, shear layer). • Closure of the RANS equations and simple models, also near a wall. • Best Practice Guidelines, and hands-on sessions using a CFD solver. Introduction to geophysical and environmental flows • Time and space scales of variability. • Geohydrodynamic equations. • Turbulence, rotation and stratification. • Rigid lid and free surface approaches. Relevant case studies (e.g., Ekman boundary layer, 2D turbulence, contaminant transport, linear and nonlinear waves, etc.).
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.) A. Dassargues A., *Hydrogeology - Groundater Science and Engineering*, CRC Press, 2019 H. B. Fisher et al., *Mixing in Inland and Coastal Waters*, Academic Press, 1979 P. Kundu et al., *Fluid Mechanics*, Elsevier, 2015 (6th ed.) C. Zheng and G.D. Bennett, *Applied Contaminant Transport Modeling*, Wiley – Interscience, 2002

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		