lmeca1321 — Fluid mechanics and transfer phenomena.

2022

5.00 credits	30.0 h + 30.0 h	Q1

Teacher(s)	Legat Vincent ;Winckelmans Grégoire ;
Language :	French
Place of the course	Louvain-la-Neuve
Main themes	Dynamical similarity and basis of dimensional analysis. Reminder of continuum mechanics (cinematics and conservation equations). Constitutive equations for viscous newtonian fluids. Notion of non-newtonian fluids. Heat conduction. Diffusion of species and Fick's law. Incompressible viscous flows (Poiseuille, Couette, annular flows). Heat transfer in developed flows. Developing flows and unsteady flows. Creeping flows and lubrification theory. Incompressible irrotational flows and lift. Boundary layers: model of Prandtl, solution of Blasius, thermal boundary layers, Reynolds analogy, von Karman integral equation. Boundary layer with mass transfer.
Learning outcomes	**At the end of this learning unit, the student is able to :** 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: • AA1.1, AA1.2, AA1.3 • AA2.1, AA2.2, AA2.3 • AA3.2, AA3.3 • AA5.5, AA5.6 • AA6.1, AA6.2 1 The course and its content is justified by the will to integrate fluid mechanics and transfers; by the necessity of ensuring to these disciplines a rigorous foundation and a general formulation, while also developing a certain number of simplified and frequently used solutions; by the will to cultivate phenomenological approaches as well as develop rigorous differential models, both approaches being necessary and complementary; by the necessity to reserve a more important place to the proper coverage of turbulence. The globality of the contents constitutes a coherent ensemble, in the framework of fluid mechanics and transfers (heat and mass). While the two courses of fluid mechanics and transferts I et II cover, together, the basics in these disciplines, the first course (I) is essentielly devoted to fondamental notions : physics, principal models, classical solutions in laminar flows, methodology (dimensional analysis, asymptotiic solutions, as for boundary layers).
Content	1. Similarity (3 hrs) • Simple cases (phenomenology) : e.g., head losses in pipes (Moody diagram), etc. (1 hr). • Dimensional analysis : Vaschy-Buckingham theorem and applications : heat transfert in pipes, lift and drag of a body, pumps, etc. (2 hrs). 2. Conservation and constitutive equations (4 hrs) • Reminders of continuum mechanics : global formulation (control volumes) and local formulation (conservation equations); constitutive equations : newtonian fluid and viscosity, Fourier law and thermal conductivity; Navier-Stokes equations; incompressible flows; compressible flows, including the case of the ideal gaz; similarity on the conservation equations and dimensionless numbers. • Introduction to non-newtonian fluids 3. Conduction (2 hrs) • Heat equation, 1-D conductionwith flat and cylindrical walls, notions of thermal resistance and of global transfert coefficient. 4. Mass transfert (2 hrs) • Conservation equations, Fick's law and mass flux of species. • Similarity on the conservation equations and dimensionless numbers. • Diffusion in a fluid at rest. 5. Solutions for incompressible flows with simplified hypotheses (11 hrs)

	• Decoupling of the momentum and temperature equations for the case with uniform viscosity; developed viscous flows (2-D, planar or axisysmmetric) : Poiseuille flow (also head losses), Couette flow, annular flows, creeping flow past a cylinder (ill-posed) and past a sphere (Stokes solution, drag) (2 hrs). • Heat transfer in Poiseuille flow; thermal entrance problem and simplified solution with "plug" flow (2 hrs). • Developing flows : entrance zone and developing length; unsteady flows : transient flow in a pipe with sudden pressure gradient, oscillating flow in a pipe with oscillating pressure gradient, started plate and oscillating plate (2 hrs). • Lubrification theory : application to the case with two flat surfaces at small relative inclination (1 hr). • Incompressible irrotational flows of a perfect fluid : Bernoulli's equation, potential functions and flows, Blasius theorem for lift (cylinder with circulation, Joukowski airfoil with circulation from Kutta-Joukowski condition) (4 hrs). 6. Boundary layers (8 hrs) • Equations for the laminar boundary layer; Blasius similarity solution for the velocity field in case of constant external velocity (2 hrs). • Displacement and momentum thicknesses; friction coefficient (1 hr). • Relation between the total temperature field and the velocity field, in case of fluids with unitary Prandtl numbers (Crocco) : contant temperature wall and adiabatic wall; similarity solution in cases with general Prandtl number and negligible dissipation, Reynolds analogy (2 hrs). • Case with variable external velocity : von Karman integral approach, introduction to the concept of separation (2 hrs). • Laminar boundary layer with mass transfer (1 hr)
Inline resources	https://perso.uclouvain.be/vincent.legat/teaching/meca1321.php
Bibliography	• Notes de cours et/ou transparents des titulaires. • 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. • H. Lamb, "Hydrodynamics", sixth edition, Cambridge University Press 1932, Dover Publications (paperback). • L. Rosenhead, "Laminar boundary layers", Oxford University Press 1963, Dover Publications (paperback). • M. Van Dyke, "An album of fluid motion", The Parabolic Press, 1982. • A. Bejan, "Heat transfer", John Wiley, Inc., 1993. • R.B. Bird, W.E. Stewart., E.N. Lighfoot , "Transport phenomena", Wiley int. ed., 1960. • H. Schlichting, "Boundary-layer theory", Mc Graw-Hill, NY, 1986. • L.D. Landau and E.M. Lifschitz, "Fluid mechanics", Course of Theoretical Physics vol. 6, Pergamon Press, London, 1959. • L. Prandtl and O.G. Tietjens, "Fundamentals of hydro- and aero-mechanics", Dover publ., NY, 1957. • J. Happel and H. Brenner, "Low Reynolds number hydrodynamics", Noordhoff int. publ., Leyden, 1973. • D.J. Tritton, "Physical fluid dynamics", Van Nostrand Reinhold, UK, 1985.
Faculty or entity in charge	MECA

Programmes containing this learning unit (UE)				
Program title	Acronym	Credits	Prerequisite	Learning outcomes
Specialization track in Mechanics	FILMECA	5		🔍
Master [120] in Mathematical Engineering	MAP2M	5		🔍
Minor in Mechanics	LMINOMECA	5		🔍