UCL Université catholique de Louvain

LMECA1321

2010-2011

Fluid mechanics and transfer phenomena.

5.0 credits	30.0 h + 30.0 h	2q

Teacher(s) :	Legat Vincent ; Winckelmans Grégoire ;
Language :	Français
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.
Aims :	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). *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”.*
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).
Other infos :	Pre-requisite : Continuum mechanics (MECA 2901). Practical exercices and laboratories : - These include class sessions and laboratory sessions . - The exercices will consist in direct applications of the theory (the objective being to initiate the student to practical calculation procedures and to the proper orders of magnitudes), in exercices requiring further creativity to extend the approaches covered in class (the objective being to use the concepts covered in class and to apply them to other objets or in the framework of other methods). - Measurement laboratory(ies) will be organized to confront the student to the practical and physical aspects of fluid mechanics and transfers, to the measurement techniques (methods, constraints, precision) and to the order of magnitude of the measured quantities. The personal implication of the student will be significant, while recognizing that they cannot be fully autonomous with respect to some sophisticated and/or fragile equipments. - Finally, the progressive development and/or acquisition of interactives laboratories (on CD-ROM or DVD) will further allow each student to work personnally, at his own rythm, on ensembles of sequences (visualisation of experimental results and of numerical simulation results, also animations). These cover phenomenological aspects as well as quantitative questions : visualisation, comprehension, analysis, answers to questions. References: - 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. - H. Lamb, "Hydrodynamics", sixth edition, Cambridge University Press 1932, Dover Publications (paperback). - L. Rosenhead, "Laminar boundary layers", Oxford University Press 1963, Dover Publications (paperback). - P. G. Drazin and W. H. Reid, "Hydrodynamic stability", Cambridge University Press 1985. - 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. - R. Siegel and J. Howell, "Thermal radiation heat transfer", 2nd ed., McGraw-Hill, NY, 1981. More information and grading policy is available on the web-site : http://www.uclouvain.be/45913.html
Cycle and year of study :	> Master [120] in Mathematical Engineering > Bachelor in Engineering > Bachelor in Mathematics > Bachelor in Computer Science
Faculty or entity in charge:	MECA