820757 Computational Methods in Energy Technology.

General learning objectives of the course

This is an introductory course on numerical methods in fluid dynamics and heat and mass transfer.

Even though basic knowledge of thermodynamics, fluid dynamics and heat transfer is needed, a review of the main concepts and analytical methods is carried out before starting with the numerical analysis, which is the main goal of the course.

After a brief introduction, attention is focussed on conduction heat transfer problems. First the conduction heat transfer equation is obtained and its resolution using finite-volume methods is shown. Some exercises are proposed and the students are encourage to develop their own computational code with the personalized support of the lecturers.

Next, convection heat transfer is analysed starting from their governing equations: the Navier-Stokes equations. It is very important to understand the physical meaning of these equations and each one of their terms. After that, zero-dimensional and one-dimensional problems are solved, using for the latter the step-by-step methodology. This approach is extended to elliptic problems using the Fractional Step Method or the Semi-Implicit Method for Pressure Linked Equations (SIMPLE), which can also be applied to multidimensional situations. Turbulence analysis is briefly set out.

Once the main numerical tools have been introduced, and after a brief review of radiation heat transfer analysis using the radiosity method, the numerical analysis of different thermal systems and equipment is presented. In these technological applications the different heat transfer modes (conduction, convection, radiation) are coupled. Examples of conjugated heat transfer problems can be found in the refrigeration field, HVAC (heating, ventilation and air conditioning) systems, active and passive solar energy, heat exchangers, CSP (concentrating solar power) plants, combustion engines (turbines, reciprocating engines, etc.), thermal systems in aircrafts and spacecrafts, aerodynamic designs, wind turbines, bioclimatic architecture, electric motors, electric and electronic components, TES (thermal energy storage) systems, aerospace heat accumulators, etc.

Modules

Module 1: Introduction. Conduction heat transfer. Mathematical formulation and numerical resolution using finite-volume methods. One-dimensional steady-state cases. Multidimensional steady state cases. Generalization to unsteady and multidimensional situations. Examples and proposal of exercises.

Module 2: Convection heat transfer. Mathematical formulation. Numerical resolution of the generic convection-diffusion equation; numerical schemes for the convective terms. Examples and proposal of exercises.

Module 3: Convection heat transfer in one-dimensional flows (the step-by-step method). Extension to multidimensional flows: Navier-Stokes equations (fractional step method; SIMPLE method). Examples and proposal of exercises.

Module 4: Radiation heat transfer. Review of basic concepts and method of radiosities. Examples and proposal of exercises.

Module 5: Conjugated heat transfer problems. Methodology for coupling the different fluid dynamic and heat transfer phenomena (conduction, convection and radiation). Application in the design and optimization of different thermal systems and equipment, e.g. heat exchangers, thermal behaviour of buildings, Trombe walls, thermal storage systems, etc..

Grading system (assessment)

The final grade depends on the following assessment criteria and weights:

- Partial exam: 20 %
- Final exam: 35 %
- Practical exercises (software): 45 %

Bibliography (basic)

- F.P. Incropera, T. L. Bergman, A. S. Lavine, D. P. DeWitt, Fundamentals of Heat and Mass Transfer, Wiley & Sons, 2011 (see more recent editions).
- J. H. Lienhard IV, J.H.Lienhard V, A Heat Transfer Textbook. 4th ed., Cambridge: Phlogiston Press, 2012. (a copy can be downloaded from http://web.mit.edu/lienhard/www/ahtt.html).
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- M.J. Moran, H.N. Shapiro, Fundamentals of Engineering Thermodynamics, Wiley, 2006.
- S. Patankar, Numerical Heat Transfer and Fluid Flow. McGraw-Hill, 1980.
- J.H.Ferziger, M.Peric, Computational Methods for Fluid Dynamics, Springer, 2001 (3r ed.).

References (complementary)

- G.F.Hewitt (editor), Heat Exchanger Design Handbook. Vol. I: Heat Exchanger Theory; Vol. II: Fluid Mechanics and Heat Transfer; Vol. III: Part 3: Thermal and Hydraulic Design of Heat Exchangers; Part 4: Mechanical Design of Heat Exchangers; Vol. IV: Physical Properties, Begell House Inc., 2002.
- D.G. Gilmore (ed.), Satellite Thermal Control Handbook, Aerospace Corporation Press, California, 1994.
- N. William A. 1999, Aircraft Environmental Systems, Endeavor Books, 1999.ASHRAE Handbooks: i) Fundamentals; ii) HVAC Systems and Equipment; iii) HVAC Applications; iv) Refrigeration (edited and reviewed every 4 years).
- W.F.Stoecker, Industrial Refrigeration, Volume II, Business News Publishing Company, Troy, Michigan, 1995.
- W.Vogel, H.Kalb, Large-Scale Solar Thermal Power, Wiley-VCH, Germany, 2010.
- J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons; 3rd Edition ed,, 2006.
- J.D.Balcomb (ed.), Passive Solar Building, The MIT Press, Cambridge, Massachusetts, 1992.
- J.Cook (ed.), Passive Cooling, The MIT Press, Cambridge, Massachusetts, 1989.
- X.C.Tong, Advanced Materials for Thermal Management of Electronic Packaging, Springer, New York, 2011.
- Specific technical papers regarding the practical work to be carried out by the students.