COURSE DESCRIPTION

Course Title	Computational Fluid Dynamics (CFD) methodology and applications				
Course Code	AU310				
Course Type	Compulsory				
Level	BSc (Level 1)				
Year / Semester	3rd/Spring				
Teacher's Name	Dr. Charalambos Chasos				
ECTS	6	Lectures / week	3	Laboratories/week	1
Course Purpose	The course purpose is to educate students in the application of CFD methodology for the prediction of flow processes and/or heat transfer in various geometries from simple to complex, for various flow applications in engines, turbomachines, combustion chambers etc. Furthermore, it aims to prepare students to formulate and solve flow problems by deriving the appropriate governing equations and using computer programming for the numerical solution of the problems. In addition, the course targets to introduce and train the students how to use advanced commercial CFD codes for engineering flow processes simulation. The present course is compulsory in the BSc. in Automotive Engineering programme and provides advanced theoretical knowledge and CFD methodologies for flow simulations.				
Learning Outcomes	By the completion of the course, the students should be able to: 1. Formulate and solve fluid flow and heat transfer problems by applying simplifying assumptions and using numerical techniques. 2. Calculate fluid flow and/or heat transfer data and construct plots of fluid flow and heat flux fields. Compare fluid flow and heat transfer behaviour in various geometries for wide range of conditions. 3. Explain factors influencing the fluid flow and/or heat transfer, and describe the corresponding effects of flow and heat transfer on the performance and efficiency of the associated system. 4. Select methodologies for modelling, simulating and carrying out parametric studies for the design and development of thermal and/or fluid flow systems, both for internal and external flows. 5. Write problem equations and apply various discretisation methods for the discretisation of equations at a grid. 6. Describe differencing schemes and use direct and indirect methods for the numerical solution of linear system of equations. 7. Define a problem geometry and the appropriate grid, specify boundary and initial conditions, write computer programme and solve numerically the problem. Visualise the results and validate the results against an analytical solution and/or experimental data. 8. List advanced grid generation techniques, turbulence modelling, solution algorithms and advanced CFD approaches				

Prerequisites	ME200, ME202	Corequisites	None

<table>
<tr><td>Course Content</td><td>
Introductory aspects: Principles of fluid mechanics, heat transfer and thermodynamics. Fluid flow and heat transfer problems, analytical and numerical solutions. Fluid flow and heat transfer problems formulation and computer programming solution. Problem solving with CFD computational codes and practical examples. Aspects of FORTRAN and MATLAB programming languages.
Classification of fluid flow: External and internal flows. Steady and unsteady state problems. Inviscid and viscous flow. Laminar and turbulent flow. Incompressible and compressible flow. Subsonic and supersonic flow. Summary of problem types and equations.
Conservation equations for fluid flow and heat transfer: Mass, momentum and energy conservation equations differential form. Mass, momentum and energy conservation equations integral form.
Boundary and initial conditions: Boundary conditions for steady and unsteady flows. Initial conditions for unsteady flows.
Discretisation techniques: The finite-difference method and applications. The finite-volume method and differencing schemes. Application of the finite-volume method in diffusion problems. Application of the finite-volume method in convection-diffusion problems.
Solution techniques of discretised equations: Summary of the FV method coefficients/sources and the resulting linear system of equations. Direct methods and application of the tridiagonal matrix algorithm (TDMA). Indirect methods and application of the Jacobi iteration method. Properties of numerical solution methods and error estimation.
Advanced topics in CFD: Grid generation. Turbulence modelling and the Naviers-Stokes equations averaging. Solution algorithms for pressure-velocity coupling. Large Eddy Simulation (LES). Direct numerical simulation (DNS).
Laboratory: Individual simulation Laboratory exercise for practical fluid flow problem solution and plots of field data, performed with the use of the CFD code STAR-CD at the Computer Laboratory.
Assignment: Individual assignment for diffusion or convection-diffusion problems solution with the finite-volume method and appropriate differencing schemes, with the application of numerical technique via the use of programming language (FORTRAN or MATLAB).
</td></tr>
<tr><td>Teaching Methodology</td><td>The course is delivered to the students by means of lectures, exercises solution on the whiteboard, conducted with the help of computer presentations, as well as demonstrations of geometries design in CAD software and generation/import of the computational mesh in the CFD code STAR-CD, procedure description and application of simulation execution and visualization of computational fields results . Lecture notes and presentations are available through the E-learn site of the course for students to use in combination with the textbooks and references.</td></tr>
<tr><td>Bibliography</td><td>(a) <u>Textbook:</u></td></tr>
</table>

	1. Versteeg H. K. and Malalasekera, W. "An introduction to Computational Fluid Dynamics – The Finite-Volume Method". 2nd Edition, Prentice Hall, England, 2007. **(b) <u>References:</u>** 1. Ferziger, J. H and Peric, M. "Computational Methods for Fluid Dynamics". 2nd Edition,Springer, Germany, 1999. 2. Potter, M. C. and Wiggert, D. C. "Mechanics of fluids". 3rd Edition, Prentice Hall, USA, 2002 3. Incropera, F. P. and DeWitt, D. P. "Fundamentals of heat and mass transfer", 5th Edition, John Wiley & Sons, USA, 2002 4. Ellis, T. M. R. "A structured approach to FORTRAN 77 programming". Addison-Wesley, England, 1982 5. Biran, A. and Breiner M. "MATLAB 6 for engineers", 3rd Edition, Prentice Hall, 2002
Assessment	**<u>(a) Methods:</u>** • Assignment 10% • Laboratory report 10% • Mid-term examination 20% • Final Exam 60% **<u>(b) Criteria:</u>** • The assessment criteria are included in the edited documents of the assignment and the laboratory exercise. In particular, the clarity of the content and writing, the structure, the methodology description, the quality of results plots and calculations, the discussion and conclusions are assessed. • The mid-term exam is done during the seventh week of the semester, which assesses the students' performance on the subject matter taught during the first six weeks of the semester. Two questions ask for the application of the finite difference and the finite volume methods for fluid flow and/or heat transfer problems. The students are assessed on the correctness of the methodology and calculations, the diagrams and their results discussion/explanation. • The final exam includes four questions (theoretical and numerical/analytical) and assesses students on the subject matter of the course and their ability to apply a method, use numerical algorithms, calculate the solution and discuss or compare their results.
Language	English