MEG603: Computational Fluid Mechanics

Program and Course Code	Mechanical Engineering Program **MEG603**
Course Title	Computational Fluid Mechanics
Credit Hours	3
Instructor	Dr. Isam Janajreh
Contact Information	Email: ijanajreh@masdar.ac.ae Tel. 02 810 9130
Office Hours	Two hours for every hour of class, TBA in beginning of semester
Bulletin Course Description	This course provides engineering applications of computational fluid dynamics with background information on the most common numerical methods; two dimensional inviscid and viscous flows; boundary layer flows; and an introduction to three dimensional flows. Applications will be illustrated utilizing FLUENT code.
Pre-requisites	MEG501 or equivalent, undergraduate numerical analysis, and Partial differential equations, or equivalents. Some programming (Matlab, C, Fortran) experience is also helpful.
Co-requisites	None
Course Objectives (Learning Outcomes of the Course)	After taking this course students will be able to: • Classify Partial Differential Equations and identify each of the temporal, advective, diffusion, and source terms. • Understand the appropriate discritization method for each of the temporal, spacial and diffusion terms as well as its implicit versus explicit discritization • Understand the difference and imposition of boundary conditions • Distinguish between finite difference, finite element and finite volume discritization methods. • Use the different solution methods for algebraic system, particularly the spars matrix, iterative versus direct and projection methods. • Use advanced CFD topics including multigrid, unstructured mesh, and artificial compressibility solution methods for incompressible Navier Stokes equations.

Week	Course Topics and Contents
1	**Classification of Partial Differential Equations** Scalar Hyperbolic Equation: Convection System of 1^{st} Order Linear and Quasilinear Equations
2	Characteristic variables and Riemann Invarients Right and Left Algebraic Eigenvalue Problem
3	Riemann Problem for a System of 1^{st} Order linear equations Euler Equations Flux Jacobian and Eignevectors 2^{nd} Order PDE: Hyperpolic; Parabolic and Elliptic equations
4	**Spatial and Temporal Discretization** Taylor Series and Polynomials Compact Schemes and Centered and Biased Schemes

5	Spectral Methods Temporal Discretization: Explicit and Implicit Schemes
6	**Hyperbolic Equations** Method for a Scalar Linear Equation in one Dimension Von Numann Stability Analysis
7	Unsteady Euler Equation in one Dimension: Flux Vector and Flux-Difference Splitting Boundary conditions: Reflecting and Non-Reflecting Boundary
8	Mid-Semester break
9	A scalar equation in Two Dimensions Euler Equations in Multi-Dimensions: Operator Splitting
10	**Parabolic Equations** Heat Equation in One Dimensions: Stability analysis of Explicit and Implicit Method
11	Heat Equation in two and Three Dimension: Approximate Factorization
12	**Elliptic Equations** Finite Difference for Poisson Equation
13	Iterative and Direct Methods for Sparse Linear Systems Multigrid Acceleration Technique
14	**Incompressible Navier-Stokes Equations** Projection method
15	Artificial Compressibility Method Unstructured Meshes: Finite Volume Discretization
16	**Final Exam/Project**

Out-of-class assignments	
Homework	Ten homework assignments, each due at the end of the week following its assignment date
Course Project	In addition to the HW and to emphasize the course outcome, a numerical simulation project will be assigned in middle of the semester and is due the last week of classes.

Course Grading	
Homework	25 %
Exam	15 % (after eight weeks)
Computer project	30 %
Final Exam	30 %
Total	100 %

Class/Laboratory schedule and Methodology	
Class	The class meets 15 weeks, 2 lectures per week, 75 minutes each.
Laboratory	CFD tutorial will be given to be used by the student and solving some of their HW while emphasize certain concepts. Computer laboratory will be used for CFD software applications.
Teaching and learning methodologies	A combination of white board use, Power-point slide presentation, and interactive class discussions to encourage student participation and enhance the learning.

Course Materials	
Textbook(s)	Computational fluid Dynamics, by K.A. Hoffmann and S.T. Chiang, Engineering Education System
Recommended Readings	1. High-order Methods for Incompressible Fluid Flow, Deville O.M., Fischer P. F. and Mund E. H (2002) Cambridge 2. Vector, Tensors and the Basic Equation of Fluid Mechanics, R. Aris, Dover 1962 3. Computational Fluid Mechanics and Heat Transfer, Tannehill ,J.C, Anderson D.A. 2^{nd} Ed. Taylor & Francis, 1997 4. Numerical Computation of Internal and External Flow, 2 Volumes Hirsch C. (1988) Wiley 5. Journal "Engineering Application of Computational Fluid Mechanics"
Instructional material and resources	A course website will be set at the beginning of the semester where all course necessary material will be posted including homework assignments and solutions.
Relationship of course objectives to IDDP Program outcomes	• Outcome 1: Demonstrate appropriate depth and breadth of knowledge that is at the frontier of their disciplines in differential system of equations, potential and viscous fluid. • Outcome 2: Use skills of interdisciplinary scholarship and research to integrate multiple perspectives. • Outcome 3: Understand and value diverse approaches to solving critical problems in research and to creating new knowledge judged by international standards. • Outcome 4: Work effectively in a multidisciplinary collaborative environment using highly developed cognitive and creative expert skills and intellectual independence.