جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Computational Fluid Dynamics - ME 305B

Division	Physical Science and Engineering Division
Course Number	ME 305B
Course Title	Computational Fluid Dynamics
Academic Semester	Fall
Academic Year	2018/2019
Semester Start Date	08/26/2018
Semester End Date	12/11/2018
Class Schedule (Days & Time)	09:00 AM - 10:30 AM | Tue Thu

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Ravindra Samtaney	ravi.samtaney@kaust.edu.sa	+966128082958		**By appointment**

Teaching Assistant(s)

Name	Email
N/A	N/A

Course Information

Comprehensive Course Description	This is an advanced course on Computational Fluid Dynamics (CFD). The course will cover multidimensional hyperbolic conservation laws with emphasis on the Colella unsplit method for Euler equations. Higher order shock capturing schemes such as WENO will be covered. High-order compact finite difference schemes will be covered, and differences between high-resolution and high-order accuracy, dissipation vs. dispersion explained in detail. A hybrid WENO-compact scheme will be examined in detail. Methods to solve the incompressible Navier-Stokes equations will be examined. Multigrid theory will be presented for the pressure Poisson equation. Advanced topics such as adaptive mesh refinement, fully implicit Newton-Krylov methods, preconditioning and parallel computing on modern supercomputing platforms will be discussed. The course is based on reading a number of classic papers in CFD; and learning is via hands-on programming exercises. Students will program the Colella unsplit method for a scalar equation, WENO method in one dimension, develop their own high-resolution finite difference scheme, implement a part of a multigrid Poisson solver. A course project involving programming will be part of the course evaluation in addiiton to a midterm examination.
Course Description from Program Guide	Introduction to floating point arithmetic. Introduction to numerical methods for Euler and Navier-Stokes equations with emphasis on error analysis, consistency, accuracy and stability. Modified equation analysis (dispersion vs. dissipation) and Von Neumann stability analysis. Finite difference methods, finite volume and spectral element methods. Explicit vs. implicit time stepping methods. Solution of systems of linear algebraic systems. Higher-order vs. higher resolution methods. Computation of turbulent flows. Compressible flows with high-resolution shock-capturing methods (e.g. PPM, MUSCL, WENO). Theory of Riemann problems and weak solutions for hyperbolic equations.
Goals and Objectives	Student will understand how to program the WENO method, generate their own high-resolution compact finite difference method, understand the difference between dissipation and dispersion errors, and have hands-on experience with a multigrid solver that they will be involved in coding some portions of it. Students will develop a project proposal and develop a code for the class project in teams of two: thus they will gain exposure on how to work in a collaorative team and develop ideas to propose.
Required Knowledge	A thorough knowledge of material covered in ME305A along with programming skills. Students will be required to have excellent applied mathematics knowledge of partial differential equations.

Reference Texts	**Reference Texts:** -Computational Fluid Dynamics John Anderson (Author) -Numerical Computation of Internal and External Flows, Volume 1, Second Edition: The Fundamentals of Computational Fluid Dynamics. Author: Charles Hirsch Publisher: John Wiley and Sons -Numerical Computation of Internal and External Flows, Computational Methods for Inviscid and Viscous Flows (Wiley Series in Numerical Methods in Engineering) (Volume 2) Author: Charles Hirsh Same publisher as Vol 1 -Computational Methods for Fluid Dynamics Joel H. Ferziger and Milovan Peric (Authors) -Finite Difference Methods for Ordinary and Partial Differential Equations: Steady-State and Time-Dependent Problems (Classics in Applied Mathe- matics) Randall Leveque (Author)
Method of evaluation	**40.00**% - Course Project(s) **30.00**% - Midterm exam **30.00**% - Homework /Assignments
Nature of the assignments	All homeworks will be based on programming numerical methods and techniques learned in class.
Course Policies	All students are supposed to work independently on homework assignments. All students must have access to a computer (desktop or laptop). All computer homework assignments require you to write a code in Fortran, C or C++. Matlab is also acceptable. Java, Pyhton or other languages will not be acceptable. Please ensure that you setup a suitable computing environment for yourself, i.e. have installed compilers for C, C++ and/or Fortran. Also, install one or more visualization packages of which I recommended installing VisIt and gnuplot. Every computer homework must be submitted electronically with the code, a procedure so that the code can be compiled, build and executed; a report, plots of results and discussion of results. Attendance for class lectures in mandatory.
Additional Information	

Tentative Course Schedule *(Time, topic/emphasis & resources)*		
Week	**Lectures**	**Topic**
1	Tue 08/28/2018	Introduction to CFD
1	Thu 08/30/2018	Multidimensional Euler Equations - Unsplit method
2	Tue 09/04/2018	WENO Methods
2	Thu 09/06/2018	WENO Methods Continued
3	Tue 09/11/2018	High order finite differences
3	Thu 09/13/2018	Resolution vs. accuracy
4	Tue 09/18/2018	Projection method for incompressible NS equations
4	Thu 09/20/2018	Projection method for incompressible NS equations (Continued)
5	Tue 09/25/2018	Poisson and heat equations revisited
5	Thu 09/27/2018	Multigrid method
6	Tue 10/02/2018	Multigrid method (continued)
6	Thu 10/04/2018	Analysis of smoothers
7	Tue 10/09/2018	Local Fourier analysis
7	Thu 10/11/2018	Midterm
8	Tue 10/16/2018	Pseudo-spectral method for turbulence simulations
8	Thu 10/18/2018	Nonlinearly implicit methods
9	Tue 10/23/2018	Newton-Krylov
9	Thu 10/25/2018	Preconditioners for NK
10	Tue 10/30/2018	Full approximation scheme (FAS)
10	Thu 11/01/2018	Hierarchical structured adaptive meshes
11	Tue 11/06/2018	AMR - hyperbolic equations
11	Thu 11/08/2018	AMR - elliptic equations
12	Tue 11/13/2018	AMR - elliptic equations (cont'd)
12	Thu 11/15/2018	Pseudo-spectra and stability of non-normal operators
13	Tue 11/20/2018	Pseudo-spectra and stability of non-normal operators (Cont'd)
13	Thu 11/22/2018	Curvilinear coordinates/mesh generation
14	Tue 11/27/2018	Advanced topics: parallel computing
14	Thu 11/29/2018	Advanced topics: parallel computing (cont'd)
15	Tue 12/04/2018	Hybrid programming models
15	Thu 12/06/2018	Hybrid programming models (cont'd)
16	Tue 12/11/2018	Final Project Presentation

Note

The instructor reserves the right to make changes to this syllabus as necessary.