UNIVERSITY OF ABERDEEN SCHOOL OF ENGINEERING COURSE INFORMATION SESSION 2015/16

EG5XXX Computational Methods for Fluid Dynamics

CREDIT POINTS:
15

COURSE CO-ORDINATOR:
TBC

COURSE ORGANISER:
TBC

CONTRIBUTORS:
TBC

SCRUTINEER:
TBC

PRE-REQUISITE:
EG3007 (Engineering, Analysis and Methods) and EG3018 (Fluid Mechanics A) OR registered for PGCert, PgDip or MSc in Process Safety OR registered for PGCert, PgDip or MSc in Subsea Engineering.

CO-REQUISITE:
None

COURSES FOR WHICH THIS COURSE IS A PRE-REQUISITE:
None

AIMS

The course aims to provide understanding of main principles and techniques underpinning computational fluid dynamics (CFD) combining numerical methods with practical experience using appropriate software. The course develops a foundation for understanding, developing and analysing successful simulations of fluid flows applicable to a broad range of applications.

DESCRIPTION

The course will provide insight into physical phenomena in environmental and industrial fluid flows via numerical simulations. Whist this motivates the use of computational technologies, even advanced CFD software may lead to incorrect predictions of fluid flow behaviour if used without sufficient understanding of the underlying algorithms and methods. This course introduces students to computational methods for solving distinct type of partial differential equations (PDE) that arise in fluid dynamic studies.

This course will involve fundamentals of numerical analysis of PDE, introduction to computational linear algebra, discretisation techniques and numerical schemes to solve time-dependent PDE problems, error control and stability analysis, mesh-generation methods and turbulence models. Hands-on sessions with industry standard software are used to develop CFD skills.

LEARNING OUTCOMES

By the end of the course students should:

A: have knowledge and understanding of:

- Fundamental computational fluid dynamics and applications;
- Finite difference and finite volume discretisation of PDE's and how numerical techniques are applied to flow equations;
- CFD workflow procedures including mesh generation, numerical discretisation schemes and solver methods, assignment of appropriate initial and boundary conditions, pre- and post-processing data.

B: have gained intellectual skills so that they are able to:

- Select appropriate set of numerical methods and discretisation schemes for a particular fluid flow application;
- Recognise terminologies used by CFD practitioners (e.g., mesh grid, boundary conditions, numerical schemes, linear solvers, quality assurance, HPC etc);
- Assess the applicability of a particular model/method and its limitations;
- Choose appropriate type of boundary conditions and mesh-grid types for simulations and assess grid dependence;
- Set up simple CFD problems;
- Analyse and interpret data obtained from the numerical simulations.

C: have gained practical skills so that they are able to:

- Use programming languages to numerically solve 1- and 2-D time-dependent PDE's (e.g., advection-diffusion equations);

- Use commercial CFD software to simulate fluid flow regimes relevant to engineering applications.

D: have gained or improved transferable skills so that they are able to:

- Use commercial CFD software to build flow geometries, generate adequate mesh grid for an accurate solution, select appropriate solvers to obtain a flow solution and visualise the simulated data;
- Use computational tools and programming languages to support data processing and manipulation;
- Perform critical analysis on data resulting from CFD simulations.

SYLLABUS

Module 1 Introduction to CFD and Principles of Conservation: (2 lectures)

a) Workflow for CFD design and simulation;
b) Overview of mass, momentum and energy conservation principles;
c) General scalar transport equation;
d) Introduction to mesh generation technologies.

Module 2 Solution of Systems of Linear Algebraic Equations: (3 lectures)

a) Review of vector-space, properties of vector and matrix norms;
b) Direct and iterative methods (Gauss elimination, LU decomposition, Jacobi, Gauss-Seidel, SOR etc);
c) Convergence analysis.

Module 3 Review of Partial Differential Equations (PDE): (2 lectures)

a) Mathematical classification of PDE (elliptic, parabolic and hyperbolic);
b) Taylor expansion and approximate solution of PDEs;
c) Boundary conditions.

Module 4 Fundamentals of Discretisation: (3 lectures)

a) Spatial and temporal discretisation principles with finite difference methods (FDM);
b) Well-posed boundary value problem;
c) Fundamentals of Finite Element and Finite Volume Methods (FEM and FVM);
d) Examples of 1-D steady-state heat conduction problem.

Module 5 Introduction to Mesh-based Methods: (5 lectures)

a) Numerical techniques for time discretisation (implicit, explicit and Crank-Nicolson schemes);
b) Discretisation schemes for advection-diffusion problems;
c) Navier-Stokes equation: discretisation staggered / collocated grids, SIMPLE algorithm.

Module 6 Introduction to Turbulence Modelling: (3 lectures)

a) Introduction to statistical representation of turbulent flows (homogeneous and isotropic turbulence);
b) General properties of turbulence quantities;
c) Reynolds-averaged Navier-Stokes (RANS) equation;
d) Introduction to the main turbulence models (κ-ε, LES and DNS).

Module 7 Numerical CFD Simulations (hands-on sessions): (14 h of lab-activities)

a) Initial training on industry standard CFD software;
b) Mesh generation and grid quality analysis;
c) Simulation of 2-D advection problem;
d) Simulation of 2-/3-D steady-state and time-dependent fluid flows (discipline specific).

TIMETABLE

Lectures: 1 two-hours + 1 one-hour per week (over 6 weeks);
Practicals: 1 two-hours per week (over 5 weeks);
Tutorials: 1 one-hour per week.

ASSESSMENT

1st attempt: 1 two-hour written examination paper (40%) and continuous assessment (60%).
Resit: A two-hour resit paper will be provided for candidates who fail the course at the first attempt.

The continuous assessment (CA) will consist of 2 components:

- Problem solving programming exercise (Modules 1-6, 20%);
- Individual report on assigned Engineering problem involving CFD simulation - discipline specific (Module 7, 40%).

These activities will be based on the submission of reports detailing assigned computational work. Detailed information relating to the format of reports will be given during course contact time.

Notes on Assessment:

- Students are required to pass both the examination and the continuous assessment in order to pass the course. A fail in the exam will not be condoned by a pass in other elements of assessment;
- In the case of a fail in any element of assessment the overall course grade will be limited to E1;
- Candidates who fail the written examination at the first attempt will be required to pass the *resit* examination;
- Candidates who pass the examination at the first attempt but fail to pass the CA elements will be required to pass the *resit* of the failed CA component(s);
- **Penalties** for late or non-submission of in-course work are defined in the Undergraduate Student Handbook which is available on the *MyAberdeen* pages for each course. If you are absent on medical grounds or other good cause, the University's policy on requiring a medical or self-certificate can be found at:
  www.abdn.ac.uk/staffnet/teaching/aqh/appendix7x5.pdf
  You are strongly advised to make yourself fully aware of your responsibilities if absent due to illness or other good cause. In particular, you are asked to note when self-certification of absence is permitted or if you are required to submit a medical certificate. All absences (medical or otherwise) should be reported through *MyAberdeen*, where you can access a student absence form for completion. *MyAberdeen* will allow you to upload any required supporting documentation, such as a medical certificate.

FORMAT OF EXAMINATION

Candidates must attempt **ALL FOUR** questions. All questions carry 25 marks. Notes:

- Candidates are permitted to use approved calculators only;
- Candidates are permitted to use the Engineering Mathematics Handbook, which will be made available to them.

FEEDBACK

- Students can receive feedback on their progress with the Course on request at the weekly tutorial/feedback sessions;
- Students are given feedback through formal marking and return of practical reports;
- Students requesting feedback on their exam performance should make an appointment within 2 weeks of the publication of the exam results.

RECOMMENDED BOOKS

1. J.H. Fereziger and M. Peric, *Computational Methods for Fluid Dynamics*, 2001;
2. H. Versteeg and W. Malalasekra, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, 2007;
3. W.H. Press, S.A. Teukolsky, W.T. Vetterling, B.P. Flannery, *Numerical Recipes: The Art of Scientific Computing*, 2007;
4. J. Kiusalaas, *Numerical Methods in Engineering with Python*, 2014;
5. J. Kiusalaas, *Numerical Methods in Engineering with Matlab*, 2009;
6. O.C. Zienkiewicz and R.L. Taylor, *The Finite Element Method -- Fluid Dynamics (Vol 3)*, 2004;
7. G.H. Golub and C.F. Van Loan, *Matrix Computations*, 1996;
8. C. Hirsh, *Numerical Computation of Internal and External Flows (Vols 1 and 2)*, 2002.

INSTITUTIONAL INFORMATION

Students are asked to make themselves familiar with the information on key institutional policies which have been made available within *MyAberdeen*,

https://abdn.blackboard.com/bbcswebdav/institution/Policies

These policies are relevant to all students and will be useful to you throughout your studies. They contain important information and address issues such as what to do if you are absent, how to raise an appeal or a complaint and how seriously the University takes your feedback.

These institutional policies should be read in conjunction with this programme and/or course handbook, in which School and College specific policies are detailed. Further information can be found on the University's Infohub webpage or by visiting the *Infohub*.