# Engineering Tripos Part IIB, 4A2: Computational Fluid Dynamics, 2017-18

### Module Leader

Dr T P Hynes [1]

### Lecturer

### Lab Leader

### Timing and Structure

Michaelmas term. Coursework with integrated lectures. Assessment: 100% coursework.

### Prerequisites

3A1 and 3A3 assumed. Pre-module reading about Fortran helpful

## Aims

The aims of the course are to:

- provide an introduction to the field of computational fluid mechanics.
- help students develop an understanding of how numerical techniques are devised and analysed with solution of fluid flow problems as the target.
- provide some experience in the software engineering skills associated with the implementation of these techniques in practical computer codes.
- illuminate some of the difficulties encountered in the numerical solution of fluid flow problems.
- Overview the nature of simulation in the future and advanced methods relating to this

## Objectives

As specific objectives, by the end of the course students should be able to:

- formulate numerical approximations to partial differential equations.
- write computer programs for solving the resulting difference equations.
- understand the limitations of numerical methods and the compromises between accuracy and mean time.
- appreciate the power of numerical solutions to predict complex flows, including shock waves.
- develop the critical skills necessary to respond to and audit simulations produced by CFD for complex flow problems.

## Content

This is a course work based project. The students have to write a Computational Fluid Dynamics (CFD) program - in Euler mode with time marching. There is also some basic mesh generation, preprocessing and post processing tasks. The assessment is through two reports. The first report demonstrates the performance of a basic CFD program and some discussion on general aspects of CFD. This needs to be handed in week 6 of the Michaelmas term. The 2nd report demonstrates the coding and performance of more advanced CFD algorithms with discussion on a selected advanced CFD topic. The performance and traits of the extended CFD code are contrasted with expected traits for a range of subsonic and transonic flows. The final report is handed in at the end of the Michaelmas term. The course also allows for some creativity through the design of novel algorithmic approaches.

**Introduction and Basic Numerical Concepts (2L including examples, plus demonstrations)**

- The proper use of CFD and the equations used
- Finite difference, finite volume, finite element approaches
- Difference scheme and molecules;
- Stability
- Dispersion and Diffusion errors, Cell Re.
- Boundary conditions

**Introduction to Advanced Concepts (6L) (Prof. P.G. Tucker)**

- Advanced numerical techniques
- Turbulence modelling
- Mesh generation
- Advanced simulation
- Aerospace CFD in industry lecture
- Pre and post processing

## Coursework

Progress Check/Brief Report/Week 6 of Michaelmas term/25%
Coursework/Report/End of Michaelmas term/75%

***Mesh Generation and Preprocessing*** (Coursework: approx 2 hours)

- Conversion to Fortran; examples of Fortran programs
- Mesh generation for simplified geometries (eg bend, nozzle, hump, airfoil)
- Preprocessing

***2-D Euler, Time Marching CFD Program***

(Coursework: 5 mini-exercises of about 2-4 hours each, forming a 16 hour mini-project)

1. Finite volume discretisation, evaluation of fluxes. (4h)
2. Application of boundary conditions. (2h)
3. Time Iteration, simple LAX method. (2h)
4. Convergence & accuracy testing. (4h)
5. Enhancements, e.g. deferred corrections, Adams - Bashforth RK integration, use of energy equation. (4h)
6. Exploration of post-processing

| Coursework | Format | Due date<br>& marks |
|---|---|---|
| **[Coursework activity #1 title / Interim]**<br>Coursework 1 brief description<br>Learning objective:<br>•<br>• | Individual/group<br>Report / Presentation<br>[non] anonymously marked | day during te<br>Thu week 3<br>[xx/60] |

| Coursework | Format | Due date<br><br>& marks |
|---|---|---|
| **[Coursework activity #2 title / Final]**<br><br>Coursework 2 brief description<br><br>Learning objective:<br><br>•<br>• | Individual Report<br><br>anonymously marked | Wed week 9<br><br>[xx/60] |

## Booklists

Please see the Booklist for Group A Courses [2] for references for this module.

Main course text is:

Tucker P. G**.** 2016. Advanced computational fluid and aerodynamics, *Cambridge University Press, ISBN: 9781107428836.*

Also, useful advanced material can be found in this text.

Tucker P. G. 2013. Unsteady computational fluid dynamics in aeronautics, *Springer, ISBN 978-94-007-7048-5.*

## Examination Guidelines

Please refer to Form & conduct of the examinations [3].

## UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

### GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

### IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

**IA2**

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

**KU1**

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

**KU2**

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

**E1**

Ability to use fundamental knowledge to investigate new and emerging technologies.

**E2**

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

**E3**

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

**US1**

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

**US2**

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

**US3**

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

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**Links**
[1] mailto:tph1@cam.ac.uk
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