Engineering Tripos Part IIB, 4A12: Turbulence & Vortex Dynamics, 2021-22

Module Leader

Prof P Davidson [1]

Lecturers

Prof E Mastorakos and Prof P Davidson

Timing and Structure

Lent term. 16 lectures (including examples classes). Assessment: 100% exam. NOTE: The first 8 lectures will be delivered online.

Prerequisites

3A1 assumed; 3A3 useful

Aims

The aims of the course are to:

- introduce the physical basis of turbulence as well as its practical implications for engineers; turbulence is a common feature of fluid flows in the atmosphere and the ocean, in aerodynamics and in chemically-reacting flows such as combustion.
- introduce the basic rules of vortex dynamics, which is identified as controlling energy transfers between different scales in a turbulent flow.

Objectives

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

- be aware of the turbulent nature of most flows of interest to engineers and its influence on the transfer processes involving momentum, heat and mass.
- interpret fluid motion in terms of the creation and transport of vorticity.
- understand energy transfer between mean flow and turbulent fluctuations (Reynolds stresses).
- understand energy transfer between the different scales of turbulence and the mechanism of dissipation.
- be aware of the more common phenomenological models of turbulence currently used by engineers and of their underlying assumptions and limitations.

Content

Turbulence and Vortex Dynamics (16L)

- Introduction to turbulence: Pictures of turbulence. Universality of turbulence in flows as the final result of instabilities. Engineering consequences.
- Some simple illustrations of vortex dynamics: The persistence of rotation (angular momentum) in flows. Another description of fluid dynamics: the vorticity equation. Lift and induced motion, with application to aerodynamics and hovering insects. Swirling flows with application to tornadoes, hurricanes and tidal

vortices.
- Basic concepts in turbulence theory: Order from chaos - Reynolds decomposition and Reynolds equation. Kinetic energy - Production and Dissipation. Introduction to the different scales in Turbulence, from the integral scale to Kolmogorov's micro-scale. Wall-bounded shear flows. Vortex dynamics at work at the large and small scales (worms).
- Phenomenological models of turbulence: Prandlt's Mixing length and k - e model: their assumptions and limitations. Other models. What can be expected from these turbulence models in terms of velocity and heat transfer.
- Current trends in industrial fluid mechanics.

Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] 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.

E3

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

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

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

US4

An awareness of developing technologies related to own specialisation.

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