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

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

The UK Standard for Professional Engineering Competence (UK-SPEC) [3] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [4] which sets out the standard for degree accreditation.

The Output Standards Matrices [5] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links
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