Engineering Tripos Part IIB, 4A7: Aircraft Aerodynamics and Design, 2019-20

Module Leader
Dr JP Jarrett

Lecturers
Dr JP Jarrett and Dr CA Hall

Lab Leader
Dr JP Jarrett

Timing and Structure
Michaelmas term. 12 lectures + coursework. Assessment: 100% coursework.

Prerequisites
3A1 and 3A3 assumed

Aims
The aims of the course are to:

- develop the basic ideas necessary to understand some advanced concepts in aerodynamics.
- cover the aerodynamic effects that constrain an aircraft design.

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

- have an appreciation of the aerodynamic factors likely to feature in the designs of new aircraft.
- have an understanding of the behaviour of boundary layers over swept wings in compressible flow.
- estimate the position of laminar-turbulent transition.
- estimate wing drag, and to be familiar with techniques for avoiding turbulent flow.
- have sufficient knowledge to be able to predict the different supersonic zones on a wing.
- understand how the basic physics can be integrated into the design of an aircraft.
- understand how to make design trade-offs.
- have a basic appreciation of the impact of aviation on the environment and possible responses.

Content
This course aims to develop the basic ideas necessary to enable the student to understand some advanced concepts in aerodynamics. In particular the course will cover the aerodynamic effects that constrain an aircraft design. The course will highlight those factors determining the configuration of aircraft for different duties relating them to the effect of compressibility at transonic speeds, the control of boundary layers to benefit from laminar...
flows and the estimation of aerodynamic loads on the aircraft structure. Coursework will illustrate basic physics, via transonic airfoil design and the integration of these basics via a study of the trade-offs made in producing a design for a given specification. The course will end by reviewing the environmental impact of aviation and show how aircraft design might change to reduce this impact.

**Introduction to transonic wings (3L, Dr J P Jarrett)**
- Review of 3A3 material: boundary layers and drag estimation;
- Transonic flow about two-dimensional aerofoils;
- Shock-boundary layer interaction;
- Supercritical aerofoils with delayed shock-induced drag rise.

**Transonic aerofoil design (4h coursework, Dr J P Jarrett)**
This coursework section will allow the interactive design of a transonic aerofoil profile on a workstation in the DPO. The aim is to consolidate the lecture material and illustrate how the various design constraints compete in practice.

**Advanced aerodynamics (3L, Dr J P Jarrett)**
- Aerodynamic challenges of high-speed flight
- Airframe/Intake integration
- Stability of swept wing aircraft
- Practical swept wing design
- Delta and slender ogival wings
- Vertical / short take-off and landing

**Aviation and the environment (6L, Dr CA Hall)**
The impact of air transport on the environment; the relationship between technology, operational practice, regulation and economics.

- Basic modelling
- The environment - overview of atmospheric chemistry, fluid dynamics & mixing; the greenhouse effect; radiative forcing.
- Airframe - aircraft range & endurance, the Breguet equation; ML/D payload, fuel and structure weight; choice of fuel. Why do airplanes fly at the altitude they do? Payload and fuel efficiency.
- Engine - simple modelling of a high-bypass ratio turbofan engine. Cycle efficiency and propulsive efficiency, trading production of NOx and CO2.
- What would an airplane look like if optimised to reduce environmental impact?

**Greener by Design (Coursework, Dr CA Hall)**
The coursework consists of a choice of one from three case studies, based on the simple modelling above to study from the perspective of environmental impact the trade-offs associated with (A) design range; (B) cruise altitude; and (C) engine overall pressure ratio. It is intended that the case studies will be spreadsheet based.

**Coursework**
- Aerofoil design/Report/Michaelmas Term/50%
- Transonic Aircraft Design/Report/Michaelmas Term/50%
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**Booklists**


**Examination Guidelines**

Please refer to [Form & conduct of the examinations](http://teaching.eng.cam.ac.uk/content/engineering-tripos-part-iib-4a7-aircraft-aerodynamics-and-design-2019-20) [3].

**UK-SPEC**

The [UK Standard for Professional Engineering Competence (UK-SPEC)](http://teaching.eng.cam.ac.uk/content/engineering-tripos-part-iib-4a7-aircraft-aerodynamics-and-design-2019-20) [4] 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 [5] which sets out the standard for degree accreditation.

The [Output Standards Matrices](http://teaching.eng.cam.ac.uk/content/engineering-tripos-part-iib-4a7-aircraft-aerodynamics-and-design-2019-20) [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

Last modified: 23/05/2019 15:45

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**Links**

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