Engineering Tripos Part IIA, 3A1: Fluid Mechanics I (double module), 2018-19

Module Leader

Dr A Agarwal [1]

Lecturers

Prof H Babinsky, Prof M Juniper and Dr J Li

Lab Leaders

Dr J Li and Prof G Hunt

Timing and Structure

Michaelmas and Lent. 32 lectures.

Aims

The aims of the course are to:

- Develop an understanding of when and where fluid flows can be modelled as incompressible and inviscid.
- Develop simple analytical and computational methods to solve incompressible and inviscid flows, and build up physical understanding through a range of practical examples.
- Introduce the effects of viscosity, and discuss boundary layer flows in some detail.
- Bring the ideas developed together in two applications sections, which consider the aerodynamics of aircraft wings and road vehicles.

Objectives

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

- Know when and where incompressible fluid flows can be modelled as irrotational.
- For two-dimensional incompressible flow, use the complex potential to determine the velocity and pressure distribution in simple geometries eg. corner flow.
- For two-dimensional incompressible flow, superimpose elementary solutions to calculate velocity and pressure distributions in a range of practical flows.
- For two-dimensional incompressible flow, know that the panel method leads to an efficient computational scheme.
- For two-dimensional incompressible flow, understand the relationship between circulation and lift.
- Use images to investigate ground effects and the influence of wind-tunnel walls.
- Use elementary solutions to calculate velocity and pressure in some simple three-dimensional flows.
- Use vortex dynamics to explain the development of simple three-dimensional flows.
- For boundary layer flows, understand the coupling between the viscous-dominated near-field flow and the inviscid far-field.
- Understand classical and integral solution techniques.
- Understand the difference between laminar and turbulent flows and transition.
- Understand the nature of flow around an aircraft.

- Understand the interaction between lift and induced velocity.
- Estimate the lift and drag of aircraft wings
- Qualitatively understand the effects of viscosity on the flow around airfoils and wings
- Describe the physical features of the flow around a road vehicle.
- Understand the origins of the aerodynamic forces on a road vehicle
- Explain how the aerodynamic forces are affected by road vehicle shape.

Content

Incompressible Flow (10L); 2 lectures/week, weeks 1-5 Michaelmas term (Prof M.P. Juniper)

- Irrotational flow and the velocity potential.
- *Two-dimensional flow:*stream function and streamline; complex potential; sources, sinks and vortices; superposition of elementary sources to determine real flows; panel method; circulation and lift; use of images.
- *Three-dimensional flow:*sources and sinks; vorticity in 3D, Kelvin's circulation theorem.
- *Viscous effects*: Navier Stokes equation, vorticity equation.

Boundary Layer Flows (10L); 2 lectures/week, weeks 6-8 Michaelmas term, weeks 1-2 Lent term (Dr J. Li)

- The boundary layer equations.
- Laminar boundary layers, similarity solutions
- Thwaites method, numerical methods.
- Turbulent boundary layers, the log law.
- Turbulent boundary layers with roughness
- Pipe flows

Applications I - Aerofoils and Wings (8L); 2 lectures/week, week 3-6 Lent term (Dr W.R. Graham)

Two-dimensional aerofoil flows:

- modelling assumptions;
- vortex sheet panel method;
- thin aerofoil theory;
- lumped parameter modelling;
- viscous effects and stall.

Three dimensional wing flows:

- general features;
- panel methods in 3D;
- lifting line theory;
- lumped parameter modelling;
- wing stall;

Applications II - Aerodynamics of Road Vehicles (4L); Applications II - Aerodynamics of Road Vehicles: 2 lectures/week, weeks 7-8 Lent term (Dr H. Babinsky)

- Review of fundamental concepts : bluff-body aerodynamics, friction vs pressure drag, 2 and 3 dimensional bodies, ground effect
- Drag of passenger cars ; boat-tailing, tail shapes, skirts
- Lift/downforce: spoilers, wings, diffusers

- Drag of haulage vehicles: tractor/trailer junction, trailer shape effects, cross-wind stability .

Coursework

Turbulent boundary layer

Flow around bodies of revolution

[Coursework title]

Learning objectives:

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Practical information:

- Sessions will take place in [Location], during week(s) [xxx].
- This activity [involves/doesn't involve] preliminary work ([estimated duration]).
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Full Technical Report:

Students will have the option to submit a Full Technical Report.

Booklists

Please see the Booklist for Part IIA Courses [2] for references for this module.

Examination Guidelines

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

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [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 [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.

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Links

[1] mailto:aa406@eng.cam.ac.uk
[2] https://www.vle.cam.ac.uk/mod/book/view.php?id=364091
[3] http://teaching.eng.cam.ac.uk/content/form-conduct-examinations
[4] http://www.engc.org.uk/ukspec.aspx
[5] http://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahep/
[6] http://teaching.eng.cam.ac.uk/content/output-standards-matrices