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Introduction



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Introduction

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This Theme Issue on 'Stability, separation and close body interactions' contains contributions from eminent applied mathematicians and fluid dynamicists on, *inter alia*, the latest developments in stability and transition of channel and boundary-layer flows, separation in laminar and turbulent boundary-layer flows, flow past bluff bodies and body impacts. The three major areas of *hydrodynamic stability theory*, *boundary-layer separation* and *close body interactions* could each form a separate issue, and so it was a somewhat daunting task to put together this Theme Issue knowing that many other authors would have liked to have contributed, and the 14 papers selected may thus only present a limited coverage of key developments. However, there is a deeper underlying connection between all the contributions in that this Theme Issue is specially dedicated to Prof. Frank T. Smith FRS, on the occasion of his 65th birthday. Prof. Smith has made seminal contributions in all the areas covered in this Theme Issue, and of course many other areas as well not covered here. Many of the authors are either former students or colleagues of Prof. Smith, or world leading scientists who have worked in the same areas.

The first few papers of this Theme Issue are concerned with stability and transition. The opening paper by Goldstein gives an overview with some new results of theory based on asymptotic methods to describe Klebanoff modes in the transition to turbulence in flat plate boundary layers. Klebanoff modes show up prominently as streaky structures far downstream and are influenced by streamwise vorticity. Goldstein and co-workers at the NASA Glenn Research Center have for many years worked on boundary-layer transition, and Goldstein is expertly placed to provide commentary on some of the key ideas concerning a rational description of Klebanoff modes in his paper. The paper by Deguchi & Hall describes some recent work on vortex-wave interactions and how they are linked to coherent structures in bounded and unbounded flows. The theory of vortex-wave interactions, and how it could help explain

self-sustained coherent structures in turbulent flows, was proposed almost 25 years ago in a remarkable series of papers by Hall & Smith [1–3]. The work remained largely ignored until recently where there has been a considerable renewed interest in the theory. The paper by Wu concerns acoustic feedback in boundary layers using triple-deck theory. In a series of papers beginning with Smith [4], it was shown how triple-deck theory could be used to describe the stability properties of boundary-layer flows in a self-consistent manner. The same techniques were successfully applied to many other stability problems and the paper by Wu is one of a series by the author in which ideas from aeroacoustics are combined with triple-deck theory in some important applications. Finally, Cimpanu & Papageorgiou discuss the application of nonlinear stability theory to electrified multi-layer flows, and in particular how this can be used to describe a new ‘pumping’ phenomenon which has potential application to microfluidic devices.

The next series of papers in this Theme Issue are concerned with laminar and turbulent boundary-layer separation. The failure of Prandtl’s classical boundary layer theory to deal with boundary-layer separation led to the simultaneous hugely important discovery of the triple-deck structure by Stewartson [5], Neiland [6] and Messiter [7], and which opened up new areas of research in the 1970s and 1980s. Much of this work is described and reviewed in [8–10]. In this Theme Issue, the paper by Conlisk & Cassel gives an excellent account of the latest work on vortex-induced steady and unsteady separation. The next paper by Logue *et al.* describes some new work on the classic problem of steady and unsteady separation in supersonic compression ramp flow where there are still many unresolved questions. The next three papers come from authors at the Vienna Institute of Technology. Whereas in the 1970s and 1980s the UK was at the forefront of work on triple-deck theory and its applications, in recent years the group led by Kluwick at the Vienna Institute of Technology has been very active and has continued the same tradition. For flow past an aerofoil at an angle of attack, classical boundary theory fails at some critical value of the angle when separation arises. Ruban [11,12] and Stewartson *et al.* [13] showed how under certain conditions when the flow is marginally separated, solutions could be extended beyond this critical value. The paper contributed by Braun & Scheichl discusses the latest work on marginal separation theory using a new method based on adjoint operators. The application of triple-deck ideas to turbulent flow past blunt bodies is addressed in the paper by Scheichl. This is the turbulent flow version of the classic problem of steady laminar flow past a bluff body discussed by Smith [14] to describe the local separation and the global wake properties. The next paper by Kluwick & Kornfeld discusses some new work on weakly three-dimensional transonic flow in slender channels with application to micro-electromechanical systems. The governing equations are again the triple-deck equations with some novel interaction laws. Boundary-layer interactions in channel flow are also discussed in the paper by Rothmayer, building on the seminal papers by Smith [15,16], but now including the effects of a magnetic field.

The final group of papers in the Theme Issue describe research on some classical problems as well some newer areas not based on triple-deck theories. The first in this group is a review by Fornberg & Elcrat on Navier–Stokes computations of flow past bluff bodies with a discussion of some open problems. It is interesting that despite huge developments in hardware, the computation of steady flow past a bluff body is still as intractable at large Reynolds numbers as it was in the 1980s. Fornberg’s [17,18] results from this period still remain the state of the art, and to improve on these will require numerical techniques which correctly capture the near and large wake properties as well the flow features near the separation point, as described in [19–21]. The next paper by Ehrenstein *et al.* shows attempts to compute the unsteady normal oscillatory motion of a flat plate. This is a very difficult computational problem, but the paper again underlines the need for theoreticians and computationalists to work together in building the models. The paper by Chernyshenko *et al.* gives a taster of some new and exciting work on the application of the sum-of-squares-polynomial technique to obtain global stability bounds. Whereas the other papers in this Theme Issue approach stability from a classical modal perspective, the paper by Chernyshenko *et al.* outlines a very different technique with some promising novel results.

The final paper is by Smith & Liu and discusses the modelling of solid body impacts on a fluid. Mathematically, this is a very difficult problem and it is noteworthy that the authors have managed to make some progress. There are many important applications to which the theory may apply as discussed in the paper, and again the work highlights the crucial interplay between theory and computations which is very often neglected.

Finally, it is a pleasure to dedicate this Theme Issue as a tribute to Prof. Frank T. Smith FRS on the occasion of his 65th birthday. His work has had great impact in many areas, as well as on many careers, and he has inspired many others to work on and continue working on stability, separation, bluff body flows and interactions. I am also most grateful to all the authors and referees for helping to shape this Theme Issue in a timely manner. Thanks are also due to the Mathematics Department at University College London for financial support which helped towards the running costs of the special meeting as part of ICNAAM2013 in Rhodes, 21–24 September 2013, held in honour of Prof. Smith's 65th birthday celebrations. Some of the papers in this Theme Issue were also presented at the meeting, and a photograph of participants who attended the meeting is appended in the electronic supplementary material.

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