Applied and Computational Mathematics Seminars 2016-2017

All seminars are held at 15:10 in Room M/2.06, Senghennydd Road, Cardiff unless stated otherwise.

Programme organiser and contact: Dr Usama Kadri

Date	Speaker	Seminar
4 October 2016	Edd Lewis	**Lattice Boltzmann methods for FENE type fluids**
	Xander Ramage	**Onset of absolute instability in Stokes layers**
	Waleed Ali	**Onset of global instabilities in the plane channel flow between compliant walls**
11 October 2016	Prof. Victor Shrira (Keele University)	**Inertial waves and deep ocean mixing** For the existing pattern of global oceanic circulation to exist there should be sufficiently strong turbulent mixing in the abyssal ocean. It is commonly believed that it is breaking of inertia-gravity internal waves which provides the required mixing. However this belief is not supported by understanding of why internal waves should break so intensely in the abyssal ocean. The specific physical mechanisms causing the breaking have not been identified and investigated. The talk discusses a very plausible mechanism leading to intense breaking of near inertial waves near the bottom of the ocean. The simultaneous account of both the horizontal component of the Earth rotation and its latitude dependence (the beta-effect) reveals the existence for near inertial waves of wide waveguides attached to the bottom. These waveguides are narrowing in the poleward direction. Near inertial waves propagating poleward get trapped in these waveguides; in the process the waves are focussing more and more in the vertical direction, while simultaneously their group velocity tends to zero and wave induced vertical shear significantly increases. This results in developing of shear

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		instability, and, hence, to wave breaking and local intensification of turbulent mixing in the abyssal ocean. It is showed that similarly to wind wave breaking on a beach the abyssal ocean always represents a “surf zone” for near inertial waves.
18 October 2016	Scott Morgan Alex McKay Danny Groves	**Stability of oscillatory rotating boundary layers** **Viscoelastic lubrication** **Contact line dynamics on heterogeneous substrates with mass transfer**
25 October 2016	Dr Alex Bespalov (University of Birmingham)	**Adaptive algorithms for high-dimensional parametric PDEs** Parametric PDEs are typical in optimisation problems and in mathematical models with inherent uncertainties (e.g., groundwater flow models).Differential operators in such PDEs depend on a large, possibly infinite, number of parameters, and naive application of numerical methods often results in the 'curse of dimensionality'. In this talk, we focus on a specific numerical method for solving such PDEs, namely on the stochastic Galerkin finite element method, for which we present an efficient adaptive algorithm. In this algorithm, we use an adaptive strategy to 'build' a polynomial space over a low-dimensional manifold in the infinitely-dimensional parameter space so that the total discretisation error is reduced most effectively,and thus the 'curse of dimensionality' is avoided. We will discuss the underlying theoretical results and demonstrate the performance of the algorithm in numerical experiments.
1 November 2016	Prof. Stephen Wilson (University of Strathclyde)	**Floating plates and evaporating droplets** In this talk I will discuss two different, but not entirely unrelated, problems in which mathematical modelling

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		and analysis can give some insight into real-world problems in fluid mechanics. In the first half of the talk I will discuss a paradigm problem motivated by recent work on fluid-structure interaction in microfluidics, namely a plate floating on the free surface of a viscous fluid [1]. In the second half of the talk I will discuss the lifetime of evaporating droplets [2]-[4]. Hopefully one or both halves of the talk will be interesting to those with an interest in the application of mathematics (and, in particular, asymptotic and numerical methods) to problems in fluid mechanics. [1] Trinh, P.H., Wilson, S.K., Stone, H.A. A pinned or free-floating rigid plate on a thin viscous film, J. Fluid Mech. 760 407-430 (2014). [2] Stauber, J.M., Wilson, S.K., Duffy, B.R., Sefiane, K. On the lifetimes of evaporating droplets, J. Fluid Mech. 744 R2 (2014). [3] Stauber, J.M., Wilson, S.K., Duffy, B.R., Sefiane, K. Evaporation of droplets on strongly hydrophobic substrates, Langmuir 31 (12) 3653-3660 (2015). [4] Stauber, J.M., Wilson, S.K., Duffy, B.R., Sefiane, K. On the lifetimes of evaporating droplets with related initial and receding contact angles, Phys. Fluids 27 (12) 122101 (2015).
8 November 2016	Dr Usama Kadri (Cardiff)	**Acoustic-gravity waves, theory and applications** Acoustic–gravity waves (AGWs) are compression-type waves generated as a response to a sudden change in the water pressure, e.g. due to nonlinear interaction of surface waves, submarine earthquakes, landslides, falling meteorites and objects impacting the sea surface. AGWs can travel at near the speed of sound in water (ca. 1500 m/s), but they can also penetrate through the sea-floor surface doubling their speed, which turns them into excellent precursors. “Acoustic–gravity waves” is an emerging field that is rapidly gaining popularity among the scientific

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		community, as it finds broad utility in physical oceanography, marine biology, geophysics, and water engineering, to name a few. This talk is an overview on AGWs, with emphasis on four major applications that I will briefly discuss: (1) early detection of tsunami; (2) transportation of water in deep ocean; (3) detection of impacting objects (with a focus on the missing Malaysian airplane MH370); and (4) nonlinear triad resonance theory of AGWs and its possible implications.
15 November 2016	Walid Almalki Martina Cracco Alex Safar Ahmed Alshehri	**Using spectral element method for in mantle convection** **Falkner-Skan flows of a non-Newtonian fluid** **Two-step computer modelling of cellular bodies with intercellular contact** **Partial differential equations using extended spectral element methods (XSEM)**
22 November 2016	Dr Georgy Kitavtsev (University of Bristol)	**Variational approaches to modelling surface energies in thin-film bilayer flows in microfluidics and martensitic twins in nonlinear elasticity** In this talk applications of non-convex variational approaches to two specific examples arising in material science will be presented. As first, it will be shown that the thin-film bilayer flows, when seen as a gradient flow of the total surface energy in the sharp interface limit, lead to a coupled system of lubrication equations equipped with the natural boundary conditions suggested previously by Kriegsmann and Miksis '03. A robust numerical algorithm for the thin-film gradient flow structure and evolution of the bilayer triple junction is then provided and tested on several examples.

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		In the second example a two-well non-convex Hamiltonian on a 2D atomic lattice describing the square-to-rectangular elastic transformations in shape-memory materials will be proposed as a model problem and subsequently analysed. The two wells (ground states) of the Hamiltonian are prescribed by two rank-one connected martensitic twins, respectively. It turns out that the Hamiltonian allows for a direct control of the discrete second order gradients and for a one-sided comparison with a two-dimensional spin system. Therefore, one can effectively proceed to a continuum limit and describe the explicit structure of the minimisers and their surface energies in the sharp-interface form. These results is recent joint work with Sebastian Jachalski, Stephan Luckhaus, Dirk Peschka and Angkana Rueland.
6 December 2016	Dr David Sibley (Loughborough University)	**Comparisons of a variety of physical and mathematical models for moving contact lines, including motion at the nanoscale** The moving contact line problem occurs when attempting to model the movement of the location where two fluid phases and a solid meet, as occurs when droplets spread (e.g. in inkjet printing), capillaries fill, insects walk on water, or in many other natural or technological instances. The problem exists when using the classical, macroscopic, equations of fluid motion as a singularity occurs in the predicted stresses and thus forces at the contact line, and the velocity is multi-valued. In this talk, we will look at the problem from the macroscale, and consider models that progressively retain more and more nanoscale physical features, culminating in an overview of results from two projects to understand motion at the nanoscale. The first is joint work with associates of the group of Prof Serafim Kalliadasis (Imperial College London) using dynamic density functional theory (DDFT) to explore the effect of the nanoscopic fluid structure on the motion of the contact line, and

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		the second is work at Loughborough to understand droplet spreading where information from the nanoscale is captured by a function that is used in a coarse-grained model. At various points, joint work with Andreas Nold, Nikos Savva, Ben Goddard, Serafim Kalliadasis, Han Yu Yin, Uwe Thiele, and Andrew Archer will be presented.
17 January 2017	Anna Kalogirou (University of East Anglia)	**Nonlinear dynamics of water waves and their impact on moving ships** The study of water waves has been an important area of research for years; their significance becomes obvious when looking at ocean and offshore engineering or naval architecture. Local weather and sea conditions can often lead to extreme wave phenomena, e.g. waves with irregular height. Waves with anomalously high amplitudes relative to the ambient waves are called rogue waves and can appear either at the coast or in the open ocean. The aim of this study is to investigate mathematically the generation and interaction of such waves and their impact on wave-energy devices and moving ships. The modelling is demonstrated by analysing variational methods asymptotically and numerically. A reduced potential flow water-wave model is derived, based on the assumptions of waves with small amplitude and large wavelength. This model consists of a set of modified Benney-Luke equations describing the deviation from the still water surface and the velocity potential at the bottom of the domain. A novel feature in our model is that the dynamics are non-autonomous due to the explicit dependence of the equations on time. Numerical results obtained using a (dis)continuous Galerkin finite element method (DGFEM) are compared to a soliton splash experiment in a long water channel with a contraction at its end, resulting after a sluice gate is removed at a finite time. The removal of the sluice gate is included

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		in the variational principle through a time-dependent gravitational potential. The Benney-Luke approximation for water waves is also adapted to accommodate nonlinear ship dynamics. The new model consists of the classical water-wave equations, coupled to a set of equations describing the dynamics of the ship. We will first investigate the dynamics of the coupled system linearised around a rest state. For simplicity, we also consider a simple ship structure consisting of V-shaped cross-sections. The model is solved numerically using a DGFEM and the numerical results are compared to observations from experiments in wave tanks that employ geometric wave amplification to create nonlinear rogue-wave effects.
24 January 2017	Jens Eggers (University of Bristol)	**Self-similar structure of caustics and shock formation** Caustics are places where the light intensity diverges, and where the wave front has a singularity. We use a self-similar description to derive the detailed spatial structure of a cusp singularity, from where caustic lines originate. We use this insight to study shock formation in the dKP equation, as well as shocks in classical compressible Euler dynamics. The spatial structure of these shocks is that of a caustic, and is described by the same similarity equation.
31 January 2017	Anne Juel (University of Manchester)	**Fluid deposition and spreading in POLED applications** Microdroplet deposition is a technology that spans applications from tissue engineering to microelectronics. Our high-speed imaging measurements reveal how sequential linear deposition of overlapping droplets on flat uniform substrates leads to striking non-uniform morphologies for moderate contact angles. We develop a simple physical model, which for the first time captures the

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		post-impact dynamics drop-by-drop: surface-tension drives liquid redistribution, contact-angle hysteresis underlies initial non-uniformity, while viscous effects cause subsequent periodic variations. Motivated by applications to the manufacture of POLED displays, we turn to the spreading of a single droplet within a recessed stadium-shaped pixel. We find that the sloping side wall of the pixel can either locally enhance or hinder spreading depending on whether the topography gradient ahead of the contact line is positive or negative. Locally enhanced spreading occurs via the formation of thin pointed rivulets along the side walls of the pixel through a mechanism similar to capillary rise in sharp corners. We demonstrate that a thin-film model combined with an experimentally measured spreading law, which relates the speed of the contact line to the contact angle, provides excellent predictions of the evolving liquid morphologies. We also show that the spreading can be adequately described by a Cox-Voinov law for the majority of the evolution.
7 February 2017	Peter Duck (University of Manchester)	**Three-dimensional boundary states: States beyond the classical form**
14 February 2017	Dr Angela Mihai (Cardiff)	**Hyperelastic constitutive models for brain tissue** In some soft biological structures, such as brain, liver and fat tissues, strong experimental evidence suggests that the shear modulus increases significantly under increasing compressive strain, but not under tensile strain, while the apparent elastic modulus increases or remains almost constant when compressive strain increases. These tissues also exhibit a predominantly isotropic, incompressible behaviour. Our aim is to capture these seemingly contradictory mechanical behaviours, both qualitatively and quantitatively, within the framework of finite elasticity, by modelling a soft tissue as a homogeneous, isotropic, incompressible, hyperelastic

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		material and comparing our results with available experimental data.
21 February 2017	Susanne Claus (Cardiff University)	**Stabilised cut finite element methods for problems involving three or more materials in complex geometries** In this presentation, we will introduce cut finite element schemes for problems with multiple materials. In the cut finite element method (CutFEM), PDEs are discretised on a regular background grid while the geometry of the problem is described independent of this background mesh. In our approach, we represent the geometry using multiple level set functions whose zero level sets describe interface and boundary locations. This means that interfaces and boundaries can intersect background mesh elements in an arbitrary manner. This yields two major challenges: (i) if an interface intersects a background element near element nodes ill-conditioning of the system matrices may occur; and (ii) to represent jumps and kinks in the solution inside elements these elements need to be enriched. This need for enrichments and for regularisation in the interface zones becomes particularly acute if three or more materials form triple or multiple junctions inside elements. In this presentation, we will show how we address these challenges and we will demonstrate the capability of our method in the context of contact problems between multiple materials.
28 February 2017	Kensuke Yokoi, Cardiff School of Engineering	**Constrained interpolation profile conservative semi-Lagrangian scheme based on third-order polynomial functions and essentially non-oscillatory (CIP-CSL3ENO) scheme** We propose a fully conservative and less oscillatory multi-moment scheme for the approximation of hyperbolic conservation laws. The proposed scheme (CIP-CSL3ENO) is based on two CIP-CSL3 schemes and the essentially non-oscillatory (ENO) scheme. In

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		this paper, we also propose an ENO indicator for the multi-moment framework, which intentionally selects non-smooth stencil but can efficiently minimise numerical oscillations. The proposed scheme is validated through various benchmark problems and a comparison with an experiment of two droplets collision/separation. The CIP-CSL3ENO scheme shows approximately fourth-order accuracy for smooth solution, and captures discontinuities and smooth solutions simultaneously without numerical oscillations for solutions which include discontinuities. The numerical results of two droplets collision/separation (3D free surface flow simulation) show that the CIP-CSL3ENO scheme can be applied to various types of fluid problems not only compressible flow problems but also incompressible and 3D free surface flow problems.
7 March 2017	Christopher Davies (School of Mathematics, Cardiff)	**Impulsively Excited Disturbances in Non-Uniform Boundary Layers** Results will be reviewed for the linearised disturbance impulse response of non-uniform boundary layers. Two distinct forms of boundary layer non-uniformity have been studied. First, we consider the global behaviour of impulsively excited disturbances in temporally steady rotating-disc boundary layers, where there is a spatial inhomogeneity which stems from the radially increasing circumferential velocity. We then consider the oscillatory Stokes layer that is driven by the time-periodic in-plane motion of a bounding flat plate. This provides a second type of boundary layer non-uniformity, which allows us to address the effects of base-flow unsteadiness upon the global development of disturbances.

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14 March 2017	Nigel Peake (Cambridge)	**The Aeroacoustic of the Owl** Many species of owl can hunt in acoustic stealth. The question of precisely how the owl actually manages to fly so quietly has remained open, but it has long been appreciated that owls which need to hunt silently possess two unique features, which are not found on any other bird, and indeed are not even found on owls which do not need to hunt silently (e.g small owls which feed on insects, or Fish Owls). First, the microstructure of the feathers on the upper wing surface is exceedingly complex, with an array of hairs and barbs which form a thick canopy just above the nominal wing surface. Second, the wing trailing edge possesses a small flexible and porous fringe which does not seem to have an obvious aerodynamic function. The research I am going to describe in this talk is part of an ongoing theoretical (at Cambridge, Lehigh University and Florida Atlantic University) and experimental (at Virginia Tech.) program, with the aims of first attempting to understand how the two unique owl features described above actually work to control the noise, and then second of designing an owl-inspired treatment which can be used to significantly reduce aerodynamic noise generation in an engineering context. The application we have in mind initially is to noise generation by onshore wind turbines, but there are many other contexts in which one wishes to reduce flow-structure noise where these ideas may be useful. In this talk I will give a flavour of the mathematical analysis, the experiments and the engineering applications.
21 March 2017	Pierre Kerfriden (Cardiff School of Engineering)	**Complexity reduction in multi scale computational modelling** With ever-increasing capabilities in terms of numerical simulations, performing computations over multiple

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		nested is becoming a realistic prospect. However, the associated numerical cost remains tremendous for anything but academic examples. We will discuss the recent development of highly automatised model reduction techniques aimed at controlling this cost. We will show that such approaches have the potential to fully enable numerical scale-linking feasible without altering the expected accuracy of the approach. In terms of applications, we will focus on examples related to the mechanics of random composite materials, more precisely linear diffusion and nonlinear fracture.
28 March 2017	Qijie Li (School of Mathematics, Cardiff) Xander Ramage (School of Mathematics, Cardiff) Alex Mackay (School of Mathematics, Cardiff)	# 1: **Numerical simulations of multiphase flows using the CIP- CSL3ENO scheme** # 2: **Absolute instability in Stokes layers** # 3: **Numerical simulations of compressible viscoelastic flow**
4 April 2017	Silvia Gazzola (Bath)	**Iterative regularization methods for large-scale inverse problems** Inverse problems are ubiquitous in many areas of Science and Engineering and, once discretised, they lead to ill-conditioned linear systems, often of huge dimensions: regularisation consists in replacing the original system by a nearby problem with better numerical properties, in order to find a meaningful approximation of its solution. After briefly addressing some classical regularisation strategies (such as Tikhonov method) and surveying some standard iterative regularisation methods (such as many Krylov methods), this talk will introduce the recent and

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		promising class of the Krylov-Tikhonov iterative regularisation methods. In particular, strategies for choosing the regularisation parameter and the regularisation matrix will be emphasised.
25 April 2017	Wade Parsons (Memorial University of Newfoundland, Canada)	**A mathematical model for acoustic-gravity waves generated by impulsive surface sources** Impulsive sources at the ocean surface generate propagating compression-type modes known as acoustic–gravity waves (AGWs) that travel in the water column at speeds near the speed of sound in water, i.e. c =1500 m/s leaving a measurable pressure signature. Possible sources include solid objects impacting the water surface, e.g. falling meteorites, landslides, sudden formation of rogue waves, or storm surges. A lot of promising work has been reported on AGWs in the last few years due to sea floor sources, with an emphasise on remote sensing as an early detection of tsunami; and only very recently have surface sources started to attract more attention. Here, we extend some of these studies to the remote sensing of general events generated at the ocean surface. To this end, we developed an analytical model for AGWs generated by an impulsive source at the free surface (the Green’s function) from which the solution for various sources can be extracted. The results are compared with various solutions in literature whereby the source is located at the sea-floor. For the validation of the model, we carried out experiments in a water tank where neutrally buoyant spheres impacted the water surface, and the generated acoustic modes were recorded from a distance using a hydrophone. The shape of the pressure signature revealed three main regions that are associated with the impact, cavitation, and secondary wave formation. Employing these findings and solving the inverse problem allows remote sensing and prediction of the main source properties.

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25 April 2017	Matthew Hunt (Brighton)	**Surface waves with external electromagnetic fields** The topic of surface waves has a long history but what has been less known is how electromagnetic fields affect the wave profiles. This has important application in magnetohydrodynamics of the Sun and with electric fields, electrolysis. This talk will contain two parts, the first will describe a weakly 2D wave which is a generalisation of the KP equation called the 2D Benjamin equation. This has beenderived in the case of interfacial waves by Kim et al. We show how this equation naturally arrives in an MHD context. This is the first such nonlinear equation for surface waves which has been derived for 3D MHD. The second part of the talk will describe how one can remove the irrotational aspect of many flows by considering a global constant vorticity and deriving a corresponding free surface equation.
2 May 2017	Danny Groves (School of Mathematics, Cardiff)	**Contact line dynamics on heterogeneous substrates with mass transfer** The contact line dynamics of two and three dimensional droplets spreading over chemically heterogeneous substrates are considered. Assuming small slopes and strong surface tension effects, a long wave expansion of the Stokes equations leads to a single equation for the droplet height where a contact line singularity is removed using a slip condition. Under a quasi-static regime we investigate cases where we have mass transfer through the substrate; modelling absorption or perhaps a needle piercing the droplet base. Utilising the method of matched asymptotic expansions, we approximate the solution of the governing partial differential equation by reducing to a set of ordinary differential equations. These ordinary differential equations are contrasted to a full numerical calculation using a pseudospectral collocation method, which, assesses the validity of the

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		approximate method, as well as offer a glimpse into non quasi-static dynamics on spreading.
9 May 2017	Eric Lauga (Cambridge)	**The Hydrodynamics of Swimming Bacteria** Many cellular organisms possess flagella, slender whiplike appendages which are actuated in a periodic fashion in fluids and allow the cells to self-propel. In particular, most motile bacteria are equipped with multiple helical rotating flagella which interact through the fluid, synchronise, and can form a tight helical bundle behind a swimming cell. We highlight in this talk two consequences of hydrodynamics for bacterial flagellar filaments. First we show how interactions between flagella mediated by the fluid allow them to repeatedly bundle and unbundle leading to reorientation of the whole cell during so-called `tumble' events. We next show how the flagellar flows induced by bacteria which have differentiated to a swarming state are responsible for large-scale fluid circulation at the scale of the whole swarm.
16 May 2017	Isaac Chenchiah (Bristol)	**Algebraic insights into martensitic microstructures** Microstructures in multi-phase solids have commonly been approached from the perspective of Calculus of Variations and PDE. Though it provides deep insights, this approach is less suitable from the perspective of materials design, that is, the effort to tailor the lattice parameters of the crystal lattices so as to optimise a desired behaviour. In this talk we consider monoclinic-I martensite, a twelve phase material and the most-common shape memory alloy. Although too complex for current Calculus of Variations tools (for example, its rank-one convex and quasiconvex hulls are

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		unknown), we show that approaching it as a convex polytope leads to a surprising discovery: There are in fact three types of monoclinic-I martensite, indistinguishable in their symmetry but differing as to their convex-polytope structure; as a consequence their set of zero- (and low-) energy microstructures is different. Curiously all known materials belong to one of these types; it is possible that the other types would have superior mechanical properties. This is joint work with Anja Schloemerkemper, University of Wuerzburg. If time permits we shall also consider the phenomenon of super-compatibility (recently introduced by R D James et al) and show that it admits of a simple geometric interpretation and cannot be extended to more than three phases.
30 May 2017	Lorenzo Morini (School of Engineering, Cardiff University)	**Waves propagation in quasiperiodic and quasicrystalline structures: dynamical trace mapping and self-similarity of the band distribution** The dynamic behaviour of quasiperiodic-generated structured rods excited by harmonic axial waves is studied. We examine structures composed of repeated elementary cells generated adopting different quasiperiodic sequences. In particular, generalised Fibonacci recursion rules, some of which representing examples of one-dimensional quasicrystals [1], are considered. Their dispersive properties are investigated by imposing Floquet-Bloch conditions and applying the transfer matrix method. The invariance properties of the transfer matrix trace, which describes the whole stop/pass band structure associated with any arbitrary elementary cell, are studied. Recursive relations between the traces of the transfer matrices corresponding to consecutive cells of the quasiperiodic sequences are derived. We show that for a specific family of generalised Fibonacci substitution rules, corresponding to the so-called

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		"precious means" structures [2], stop/pass bands within a defined range of frequencies for a given sequence are distributed following a self-similar pattern [3] and this is repeated according to a scaling law for subsequent orders. The detected self-similar structure of the stop and pass band distribution represents an important feature that can be exploited in order to design "quasicristalline" filtering devices. References: [1] Poddubny A.L. and Ivchenko E.L., Photonic quasicrystalline and aperiodic structures, Physica E, 42, (2010) 1871-1895. [2] Kolar M. and Ali M. K. One-dimensional generalized Fibonacci tilings, Phys. Rev. B, 41 (1990) 7108-7112. [3] Gei M. Waves in quasiperiodic structures: stop/pass band distribution and prestress effects, Int. J.
6 June 2017	Ned Nedialkov (McMaster University)	**(1) Structural Analysis and Numerical Solution of High-Index Differential-Algebraic Equations** Systems of differential-algebraic equations (DAEs) arise in many engineering and scientific disciplines. The index of a DAE is a measure of how difficult it is to solve it, compared to an ordinary differential equation (ODE). Problems of index 3 and higher are considered high index, and are very difficult to solve numerically. We overview Pryce's structural analysis (SA) theory and its realization in the DAETS solver (Nedialkov and Pryce), a C++ package for solving high-index DAEs. This solver can deal with fully implicit, any index, and aribrary-order DAEs.

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		We also present DAESA (Nedialkov, Pryce, and Tan), a standalone Matlab tool for SA of DAEs. It provides convenient facilities for rapid investigation of DAE structures. In particular it reveals subsystems of a DAE to a finer resolution than many other methods. Joint work with J. Pryce and G. Tan
6 June 2017	Peter Harman (CAE Tech Limited)	**Modelica and FMI Open-Standards** This talk will describe the Modelica open-standard modelling language and the FMI (Functional Mockup Interface) standard for model exchange, and their importance in engineering of complex systems for automotive, aerospace and other applications. The mathematical basis of these standards will also be covered, and how the efficient solution of arbitrary sets of Differential Algebraic Equations (DAEs) with mixed discrete-continuous behaviour is fundamental to their success.