Date	Speaker	Seminar
25 February 2020	Dr Artur Gower, University of Sheffield	**Multiple scattering between particles** Particulate materials (powders, composites, emulsions, and gases) are everywhere in nature and industry. Waves, such as sound and light, are ideal to monitor and characterise particulate materials. Yet we still do not fully understand how waves interact with these materials, especially when the position of the particles is unknown. This is primarily due to multiple scattering and complex interference patterns. To date, the prevailing method assumes that a wave will perceive the (ensemble average) particulate material as a homogeneous medium with one wave-speed and attenuation. However, I will show that, in general, the material has an infinite number of wave-speeds and attenuations all coexisting at the same time.
11 February 2020	Dr Paul Ledger, Swansea University	**Identifying hidden metallic objects at low frequencies** The location and identification of hidden conducting security threats in metal detection is an important, yet difficult, inverse problem. Applications range from food production to finding landmines and unexploded ordnance. Current approaches use simple thresholding and are incapable of determining an object's size, shape and material properties from the measurements of the perturbed magnetic field. Instead, we use an asymptotic expansion of the perturbed magnetic field, which separates the object's shape and material parameter information from its position. This allows the object to be characterised by a small number of parameters through a magnetic polarizability tensor (MPT). The inverse problem then reduces to identifying an object's location, which can be done using a MUSIC algorithm, and identifying the object using a statistical classifier based on dictionaries of MPTs invariants. For the classification, the spectral behaviour of MPTs is exploited by taking measurements over a range of frequencies, which provides additional information.
4 February 2020	Dr Hermes Gadelha, University of Bristol	**Mathematical tales of a sperm tail** Breakthrough research into the mechanics of sperm tails has profound implications for life itself, from human reproduction to the development of sustainable food production. Fluid dynamics, elasticity and mathematical biology can provide predictive insights into the mechanics of these specialised cells during their arduous journey through the often hostile environment of the female reproductive tract. Brazilian-born Dr Hermes Gadelha talks about his work at the fertile union of mathematical logic, biomechanics and medicine.

28 January 2020	Dr Pierre Ricco, University of Sheffield	**Entrainment and development of vortical disturbances in the channel entrance region** The stability and transition to turbulence in laminar shear flows still presents enormous theoretical challenges, even in the simplest geometries, such as a channel. We will be discussing recent mathematical and numerical results on the entrainment and development of vortical disturbances in the entrance region of a channel. This problem is important as a first cardinal step towards understanding how perturbations penetrate the confined region, develop and grow downstream, and eventually contribute to the flow breakdown to turbulence. We adopt an asymptotic framework in the limits of long wavelength and high Reynolds number and solve the boundary-region equations from the channel mouth to the fully developed regime. We restrict the analysis to Reynolds numbers for which the flow is linearly stable according to classical stability theory, albeit the disturbances grow algebraically and experimental studies have even shown transition to turbulence. A key aspect of the framework is the precise specification of the disturbances in the proximity of the channel mouth because their growth rates and the amplitudes strongly depend on the characteristics of the upstream flow. Matched asymptotic expansions are used to prescribe the initial flow for symmetric and anti-symmetric disturbances. We first present the initial matched-asymptotic solution and the pressure-driven high-Reynolds-number solution for the mean flow, which matches DNS and experimental results. The disturbance flow, solved numerically by casting the equations in the wall-normal velocity-vorticity formulation, is studied by varying the main parameters of the flow, such as the Reynolds number, the frequency, and the three wavelengths of the oncoming free-stream disturbance. The effect of symmetry of the oncoming disturbances is also investigated.
26 November 2019	Dr Eugeny Buldakov, UCL	**Numerical Lagrangian modelling of extreme ocean waves** The main difficulty of Eulerian numerical solvers for water waves is due to changing shape of a computational domain. There are numerous methods of dealing with this problem, all of them invariably leading to considerable complication of solvers. The natural solution is using equations of fluid motion in Lagrangian form which -- though in some cases are more complex than Eulerian counterparts-- to be solved in a fixed domain of Lagrangian coordinates. The presentation discusses the development of a numerical solver where a simple finite-difference technique applied directly to Lagrangian equations of motion of inviscid fluid. Stability of the numerical scheme and numerical dispersion relation are analysed and method of improving numerical dispersion is suggested and implemented. Problem of wave breaking is discussed and a dissipative breaking model is

		developed. A 2D version of the solver is then applied to extreme ocean waves. An extreme event in random sea is described as a deterministic focussed wave group with an amplitude spectrum related to the spectrum of the underlying random process. Evolution of such a wave group is modelled in a Lagrangian numerical wave tank and results are compared with experiments.
19 November 2019	Professor Alison Raby, University of Plymouth	**Extreme waves and the structures that dare to stand** Historic lighthouses, seawalls and breakwaters are still standing after many years, having endured an incredible battering. In the past, methods of designing structures in the coastal zone were empirical, with much of the understanding acquired by considering previous failures. More recently, our understanding of the nature of waves has encouraged a statistical approach, using long random wave realisations to identify worst responses. This presentation will describe the novel use of a design wave in the coastal zone, using a series of experimental campaigns on physical models exposed to extreme wave loading, particularly focusing on rock lighthouses.
12 November 2019	Professor Peter Schmid, Imperial College	**Koopman analysis and dynamic modes** Koopman analysis is a mathematical technique that embeds nonlinear dynamical systems into a linear framework based on a sequence of observables of the state vector. Computing the proper embeddings that result in a closed linear system requires the extraction of the eigenfunctions of the Koopman operator from data. Dynamic modes approximate these eigenfunctions via a tailored data-matrix decomposition. The associated spectrum of this decomposition is given by a convex optimization problem that balances data-conformity with sparsity of the spectrum. The Koopman-dynamic mode process will be discussed and illustrated on physical examples.
5 November 2019	Professor Derek Moulton, University of Oxford	**Morphorods: the mechanics of growing elastic rods** Filamentary structures display a wide range of patterns and behaviours, such as in polymers, vines, axons, trachea, and elephant trunks, to name a few. Mechanically, a key feature prevalent in biological filaments is growth. Growth is the critical element underlying biological pattern formation and may also be utilised in other ways, for instance to generate movement or provide mechanical support against external loads. Due to their inherent slenderness, the mechanical behaviour of growing filaments is well-characterised by a one-dimensional continuum representation. We have in recent years developed a framework for modelling such structures by including growth in classical elastic rod equations; we term these morphoelastic rods or simply morphorods. In this talk I will first briefly outline our framework and demonstrate the variety of applications and patterns that can be generated. I will then turn to our current efforts to confront the significant challenge of incorporating tissue level

		properties in the morphorod setting. A motivating example is in gravitropic growth, in which a branch or stem develops curvature in response to an external field (gravity). To model such a multiscale process we have developed a robust system of mapping from growth in a 3D finite elasticity setting to a 1D morphorod.
22 October 2019	Professor Catherine Powell, University of Manchester	**Adaptive stochastic Galerkin approximation for parameter-dependent linear elasticity problems** In this talk, we give an overview of some recent work on the use of stochastic Galerkin mixed finite element methods (SG-MFEMs) for performing forward uncertainty quantification in parameter-dependent linear elasticity equations. Starting from a three-field PDE model in which the Young's modulus is represented as an affine function of a set of parameters, we discuss how to implement SG-MFEM approximation and introduce a novel a posteriori error estimation scheme. We examine the error in the natural weighted norm with respect to which the weak formulation is stable. Exploiting the connection between this norm and the underlying PDE operator also leads to an efficient preconditioning strategy. Unlike standard residual-based error estimation schemes, the proposed strategy requires the solution of auxiliary problems on carefully constructed detail spaces on both the spatial and parameter domains. We establish upper and lower bounds for the SG-MFEM approximation error in terms of the proposed estimator. The constants in the bounds are independent of the Poisson ratio as well as the SG-MFEM discretisation parameters, meaning that the estimator is robust in the incompressible limit. Finally, we briefly discuss proxies for the error reduction associated with potential enrichments of the SG-MFEM spaces and use these to develop an adaptive algorithm that terminates when the estimated error falls below a user-prescribed tolerance.
15 October 2019	Dr Ian Griffiths, University of Oxford	**iPhones, Dysons and Cheerios: using fluid dynamics to aid technology** As technology continues to advance, new strategies involving a range of scientific disciplines are required. Mathematicians can provide frameworks to predict operating regimes and manufacture techniques. In this talk we show how mathematics can be used to help in the fabrication of precision glass, for smartphones and new flexible devices; the development of superior filters for vacuum cleaners; and the manufacture of unusual cereal shapes (like Nestlé Alphabet cereals)
8 October	Professor Jonathan Healey, Keel University	**Fractal neutral curves in the linear stability of shear flows** Rayleigh showed that the linear stability properties of inviscid shear layers are described by a second order linear ODE, and the effects of buoyancy due to fluid density variations were included by Taylor and Goldstein in 1931, resulting in one

additional linear term in Rayleigh's equation (for weakly varying density). Rayleigh's inflexion point theorem no longer applies and Taylor gave an example where stable stratification (density increasing with depth) destabilizes an inflexionless flow. The Taylor-Goldstein equation is widely used in many geophysical and astrophysical flow applications. In this talk we show that this linear ODE can produce neutral curves (separating stable from unstable regimes) with fractal properties, and discuss possible implications for nonlinear dynamics.