LONDON MATHEMATICAL SOCIETY
EST. 1865

NEWSLETTER

Issue: 515 - May 2025

LATIN SQUARES VIA GRAPH THEORY

PRIMARY SCHOOL MATHS CLUB

NOTES OF A NUMERICAL ANALYST

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Charity registration number: 252660

COVER IMAGE

Credit: Peter Rowlett and Gwilym Jones. See ‘Primary School Maths Puzzle and Games Club’.

Do you have an image of mathematical interest that may be included on the front cover of a future issue? Email images@lms.ac.uk for details.

ISSN: 2516-3841 (Print)
ISSN: 2516-385X (Online)
DOI: 10.1112/NLMS

NEWSLETTER WEBSITE

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Bulletin and *Journal of the LMS* – Seeking Your Feedback

Regular readers of the *LMS Newsletter* will know that the editors and Publications Committee have all been working hard over the last few years to improve the two journals' editorial processes and thereby to make them the journals of choice for your papers. We would like to share some of the results of this work, and we also want your feedback on our editorial coverage.

Fast and Fair Decisions on Your Articles

We aim to provide a fair, rigorous and efficient peer review process. We are confident that our restructured board of seven sections, with each section making its own decisions overseen by the Managing Editors, is delivering consistent, reasonable decision-making without any diminution of quality.

As authors ourselves, we understand that it is particularly frustrating to wait many months only to find that a paper has been rejected. LMS editors strive to review papers with the least possible delay, and if a submission is to be rejected, the editors aim to do so at the earliest opportunity. In 2024, an initial decision of whether to reject or proceed with a full review was made for 90% of *Bulletin* papers within two months and for 82% of *Journal* papers within three months. Papers that are sent for a full review have a high probability of being accepted for publication. Last year, 67% of *Bulletin* and 83% of *Journal* submissions that had been sent for a full review were accepted.

Ensuring That We Serve All of Pure Mathematics

We recognise that the main body of most mathematics papers written today is read primarily by subject specialists. However, all papers submitted to the *Bulletin* and *Journal* are expected to have a motivating introduction that sets the work in context and can be understood and appreciated by researchers outside the paper's immediate specialism. With this caveat, the journals welcome submissions of high-quality papers in the broad areas covered by the editorial board, which allows us to serve more of the community.

Your Feedback on Our Editorial Coverage

We want to be journals of choice for the entire pure mathematics community. It is, therefore, essential that any mathematician considering submitting to one of our journals is able to find an appropriate editor. The LMS Publications Committee has carried out a careful analysis of our editorial coverage, which feeds into our annual process of new editorial appointments. However, there is always the possibility that there are gaps of which we are unaware.

If you are a research-active pure mathematician, we ask that you take a look at the editorial board at lms.ac.uk/publications/BJ-Editorial-Board. If you don't see an editor whom you feel could reasonably handle your papers and to whom you would be happy to submit, let us know by contacting publications.secretary@lms.ac.uk.

Publishing Supports the Society

Choosing to publish in one of the Society's journals means that you are supporting mathematics. Every article published in our journals results in more funding for the Society, and all LMS profits from publishing are used to support mathematics. This means that the Society can award more grants, run more initiatives for early career researchers and do more to promote mathematics and support the mathematics community.

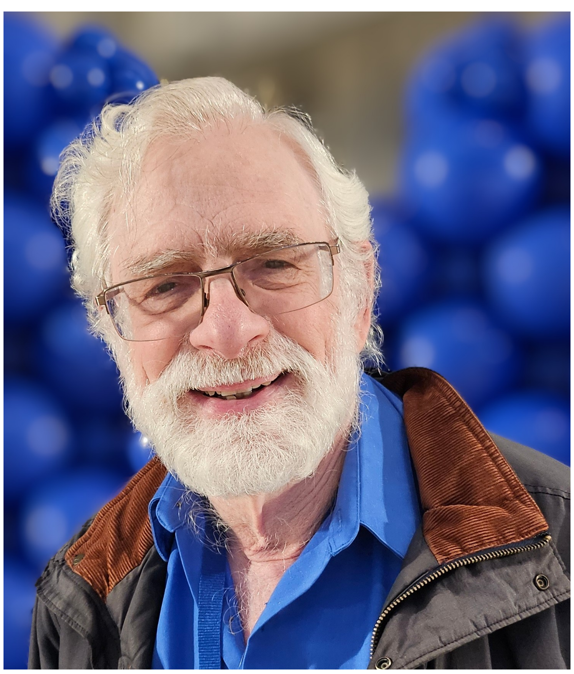
Niall MacKay
Publications Secretary
Minhyong Kim, Caroline Series, Stuart White and Julia Wolf
Managing Editors

Joint Mathematics Meeting 2025, Seattle, USA

In line with the LMS strategic objectives 'LMS in the Global Community' and 'Engaging our Community', I attended the Joint Mathematics Meeting (JMM) with Simon Buckmaster, Head of Academic Publishing. It was the first time in recent years that the LMS had a stand at JMM.

JMM started on Wednesday evening with a gala reception in the exhibition hall. The event was very well attended, with more than 50 people entering the LMS raffle to win a signed copy of Around the World in 80 Games by Marcus du Sautoy. In addition to the various activities offered on the exhibition stands, the American Mathematical Society provided a dance floor with a DJ and a dance instructor to lead the dancing. This proved to be very popular and, maybe, something we will see at future LMS events!

Thursday and Friday continued to be busy with lots of mathematicians at all career stages visiting the LMS stand to hear more about membership, grants, events and the LMS publications. Professor Thomas Drucker, LMS member and guest lecturer at JMM and Professor Steve Weintraub dropped by the LMS stand to say 'Hello.' Steve has been an LMS member for 42 years. Thanks Steve!



Professor Steven H. Weintraub

We also ran the popular Guess the Sweets in the Jar competition and had 141 entries; entrants included schoolchildren, schoolteachers, maths undergraduates, early researchers and professors. No one guessed correctly, but the winner was only one number out. The answer was 421.

One of the highlights of our visit was meeting some of our US and international members for a drink on Friday evening. We were very pleased to meet Professor Tevian Dray, Professor Jonathan Hall, Professor James Tattersall, Professor Steve Weintraub and Dr Nek Valous. We were also joined by Mrs Hall, Mrs Tattersall, SLAM committee member Karima Khusnutdinova (Loughborough), Emilian Parau (University East Anglia) and the UK delegation from Cambridge University Press.

Many of our US members spoke fondly of their time living and working in the UK and their previous engagement with the LMS at events in the US. We hope to do more of such US events in the future.

JMM ended at 12 noon on Saturday. It was then time to pack up and squeeze in a 1-hour boat tour of Seattle harbour before heading to the airport for the flight back. On behalf of the Society, I would like to thank all our LMS Members, visitors to the LMS stand and the AMS for making us so welcome. We will see you in Philadelphia for ICM 2026!

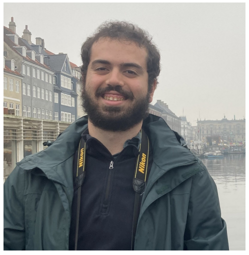
Jennifer Gunn
Head of Society Business

Cecil King Travel Scholarship

The Cecil King Travel Scholarship is a prestigious award established in name of the renowned British newspaper proprietor and businessman Cecil Harmsworth King. The funding is provided by the Cecil King Memorial Foundation to support two individuals who have demonstrated exceptional academic potential in mathematics. Two scholarships are awarded each year to finance a study or research visit abroad for a period of three months.

Awards 2025

Following this year's round of applications, the London Mathematical Society and the Cecil King Memorial Foundation are delighted to announce that Cecil King Travel Scholarships 2025 have been awarded to Mr Dimitrios Katsaounis and to Ms Nivedita Nived.



Dimitrios Katsaounis is a PhD student at the University of St Andrews. His main focus lies in the development of mathematical models in mathematical oncology. His aim is to extend the knowledge on cancer invasion and metastasis through multiscale mathematical modelling techniques, starting from the solitary cancer cell level to the holistic representation of the organism. Through numerical simulations, he seeks to gain greater insights into cancer growth and use the models as predictive tools for cancer treatment.

Dimitrios Katsaounis will visit Professor Sarah Merino-Aceituno at the University of Vienna during the summer of 2025, where he hopes to gain advanced insights into modelling and analytical techniques with the aim of stimulating scientific publications through this collaboration.

Nivedita Nived is a DPhil student at the University of Oxford. She works on functorial field theories, an approach to quantum field theory (QFT) credited to Atiyah and Segal (1988–89). This framework studies representations of cobordism categories and axiomatises the properties of the path integral, a central tool in the study of QFTs. Nivedita's research focuses on a special class of QFTs known as chiral conformal field theories, which describe various critical phenomena in condensed matter physics and serve as the building blocks of string theory. Additionally, she studies higher cobordism categories with topological defects and higher categorical targets for functorial field theories, including models for 2-Hilb and 3-Hilb, the higher categorical analogues for the category of Hilbert spaces.

Nivedita's research programme fits very well into the activities of the research group curated by Professor Dr Ingo Runkel at the University of Hamburg. The collaboration will establish new directions for Nivedita's research and significantly extend her personal network of contacts with her peers as well as with more senior researchers in the field.

The London Mathematical Society and the Cecil King Memorial Foundation believe that the scholarship programme offers various opportunities to early career mathematicians in the form of mentorships, professional development, networking and progress of the academic careers.

If you would like to find more about Cecil King Travel Scholarships and how to apply, please visit lms.ac.uk/prizes/cecil-king-travel-scholarship.

The application deadline for the 2026 programme is **15 November 2025**. The application form will be available from the LMS website in September 2025.

Valeriya Kolesnykova
Accounts, Fellowships & Membership Assistant

LMS YouTube Channel

The LMS YouTube channel has recently been updated with recordings from many of our recent events, including the *BCS-FACS Seminar*, the 2024 Annual General Meeting, *Computer Science Colloquium*, *Good Practice Scheme Workshop*, *the Spitalfields/Hirst Lecture* and the 2024 General Meeting celebrating the 200th anniversary of the birth of William Thomson, otherwise known as Lord Kelvin.

The channel also features videos from our extensive history of previous events, with talks from Roger Penrose, Matt Parker, Hannah Fry, Marcus du Sautoy, Timothy Gowers, Mark Miodownik, Katie Steckles and many more.

All the videos are free to watch. The channel is at youtube.com/londonmathematicalsociety, and if you subscribe to our channel, you will receive alerts when new videos are uploaded.

Kieran O'Connor
Events Coordinator

LMS Early Career Fellowships Award Announcement 2024/25

We are pleased to announce the awards of the LMS Early Career Fellowships for 2024/25, which are supported by the Heilbronn Institute for Mathematical Research (HIMR) and UKRI. This funding aims to provide financial support to talented UK mathematicians who have recently completed their PhD and are actively seeking postdoctoral positions. During the transition period, the Society, along with its sponsors HIMR and UKRI, provides a stipend of £1,615 per month for research visits lasting between 3 and 6 months. Additionally, there is extra funding of £800 available for relocation expenses or research collaboration visits.

The LMS Early Career Fellowships not only offer financial support for research and career development but also help to encourage collaboration and further advancement in mathematics. This year's fellows are an inspiring group with notable achievements and goals. Selected through a rigorous and competitive process, each fellow has demonstrated not only outstanding academic or professional achievements but also a passion to pursue and realise their full potential.

The Early Career Research Committee reviewed 42 applications and awarded seven fellowships to support collaborations and projects at universities both in the UK and overseas. A full list of the current fellows is available on the Society's website at lms.ac.uk/grants/lms-early-career-fellowships#Current.

Applications for next year will open in October 2025. The deadline is 14 January 2026 for fellowships starting from April 2026. For more information about the scheme and how to apply, please visit the Society's website (lms.ac.uk/grants/lms-early-career-fellowships) or direct your inquiries to fellowships@lms.ac.uk.

Valeriya Kolesnykova
Accounts, Fellowships & Membership Assistant

OTHER NEWS

Registration Is now Open for ICM 2026

The next *International Congress of Mathematicians* (ICM), to be held on 23–30 July 2026, is now open for registration. The congress, to be held in Philadelphia, PA, coincides with the 40th anniversary of the last ICM held in the USA. The event offers an exciting opportunity to meet some of the world's leading mathematicians and be inspired by the vast diversity of today's mathematics.

Early advanced registration (US$570 for full participants) will close on 1 August 2025. Read more information and register at www.icm2026.org/event/ac193975-5d24-4628-8c30-ddb23de19a8b/home.

Katherine Wright
Communications and Policy Manager

Clay Research Fellows 2025

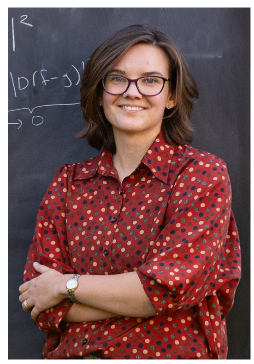
The Clay Mathematics Institute is pleased to announce that Ryan Chen, Alex Cohen and Anna Skorobogatova have been awarded Clay Research Fellowships.

Ryan Chen will receive his PhD in 2025 from the Massachusetts Institute of Technology, where he works under the guidance of Wei Zhang. Chen is an arithmetic geometer of exceptional creativity with great technical expertise. His research focuses on themes surrounding the Gross–Zagier-type formula for high-dimensional Shimura varieties, where the main aim is to relate the arithmetic intersection numbers of algebraic cycles to the special values of L-functions and their derivatives. He has established, in great generality, a new arithmetic Siegel–Weil formula, linking the Faltings heights of Kudla–Rapoport 1-cycles on integral models of unitary Shimura varieties to the first derivatives, near the central point, of non-singular Fourier coefficients of Siegel–Eisenstein series. His work has opened up new directions in understanding the arithmetic-geometric meaning of the sub-leading terms of various L-functions, including notable examples such as the standard L-functions and the adjoint L-functions associated with cohomological automorphic representations of unitary groups over totally real number fields.

Ryan Chen has been appointed as a Clay Research Fellow for five years beginning 1 July 2025. He will be based initially at Princeton University.

Alex Cohen will receive his PhD from the Massachusetts Institute of Technology in 2025, under the supervision of Larry Guth. Cohen is a broad and thoughtful researcher who has made innovative contributions to harmonic analysis, combinatorics and microlocal analysis. His work on the higher-dimensional fractal uncertainty principle is of particular note. It has important applications to the field of quantum chaos, generalising the celebrated work of Bourgain and Dyatlov to arbitrary dimensions. In this context, he also developed a higher-dimensional version of the Beurling–Malliavin theorem, a deep theorem about one complex variable from the early 1960s.

Alex Cohen has been appointed as a Clay Research Fellow for five years beginning 1 July 2025. He will be based initially at New York University.



Anna Skorobogatova obtained her PhD from Princeton University in 2024, supervised by Camillo De Lellis. She is currently an ETH-ITS Junior Fellow at the ETH in Zurich. Skorobogatova works in geometric measure theory. She has made fundamental contributions to the regularity theory of minimal surfaces and to the structural understanding of their singularities. She established the rectifiability of the top-dimensional part of the singular set of area-minimising integral currents and the uniqueness of the tangent cones at almost every singular point, solving a problem that had remained completely open in codimensions greater than 1, despite great efforts following *Almgren's Big Regularity Paper*. She has also proved that the singular set of area-minimising currents mod an integer q is a regular C^1 hypersurface aside from a lower-dimensional exceptional set, in all dimensions and codimensions and for all moduli q.

Anna Skorobogatova has been appointed as a Clay Research Fellow for four years beginning 1 July 2025.

Clay Research Fellowships are awarded on the basis of the exceptional quality of candidates' research and their promise to become mathematical leaders. For more information visit www.claymath.org.

Naomi Kraker
Administrative Manager, Clay Mathematics Institute

TIMSS 2023: Lessons for Mathematics Education in England

Trends in International Mathematics and Science Study (TIMSS) is a flagship four-yearly IEA study that assesses trends in mathematics and science performance across items aligned with England's national curriculum (in contrast with PISA, which assesses 'mathematics literacy'). TIMSS also assesses the home and school background and the mathematics and science learning experiences as reported by sample students, their teachers and their headteachers. England has participated in every cycle since 2015, and the use of 'trend items' supports a cross-series comparison of performance. TIMSS includes 9–10-year-olds (year 5) and 13–14-year-olds (year 9). The 2023 study included 59 (largely medium- and high-income) countries at year 5 and 44 at year 9.

The assessment in 2023 was published fully online for the first time. It used a group-adaptive design to accommodate a range of achievement distributions and better integrated 'problem-solving' items. Items were developed and trialled in relation to curriculum content areas and to mathematical processes of *knowing*, *applying* and *reasoning*. Scaled performance is reported relative to a 'centre point' of 500 (the mean in 1995, with associated SD of 100), and performance descriptors are exemplified in relation to four 'benchmarks'. Our analysis of the England sample (>4,000 students at each level) suggests it was fairly robust, although, due to the pandemic, the sample year groups had no standardised performance data when they were in years 2/6, respectively. International Study materials (timss2023.org) and England reports[1] provide details. Here, I focus on key findings in relation to mathematics performance and indicators for future participation, where relevant using significance at the 5% level.

At year 5, students on average achieved close to their 2019 all-time high — a reassuring finding post-pandemic and likely supported by considerable DfE investment in the NCETM and maths hubs. However, further analysis of average performance showed that scores were disproportionately contributed to by responses to *data* questions, while students underperformed in *measurement and geometry*, an area of the curriculum known to be critical for future mathematical development. Similarly, scores for *knowing* were significantly above those for *reasoning* and *applying*.

At year 9, the students' average score was higher than ever before, exceeded only by that of students in the five highest-performing east Asian countries, again, an encouraging finding. However, in relation to the curriculum balance achieved, performance was highest in *number* and *data/probability* and significantly lower in *algebra* and *geometry and measurement*. Regarding cognitive domains, it was also significantly lower in *reasoning* than in *knowing* or *applying*. These lower-scoring content and cognitive areas are, of course, pillars for future mathematical development.

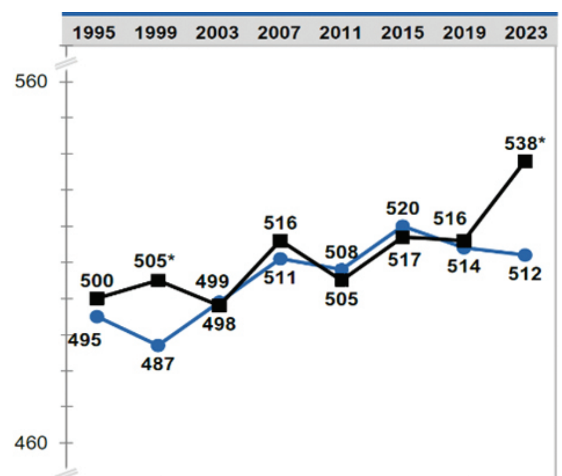


Figure 1. TIMSS England performance by gender over time.
* significant gap in favour of boys

In both year groups and in terms of equity of access to high-quality mathematical functioning, TIMSS 2023 showed an increase in the range of scores, driven by strong performance at the top end. The average socio-economic gap increased further from 2019. It also revealed the widest gender gap ever recorded by year 5 students in England and the widest internationally in year 9, in favour of boys (Figure 1), who significantly outperformed girls in almost all bench-

[1] www.gov.uk/government/publications/trends-in-international-mathematics-and-science-study-2023-england

marks. Disappointingly, TIMSS 'basket' measures for *confidence in mathematics*, for *liking mathematics* and for both *aspiring to continue to study* and *aspiring to work with mathematics*, all important for progression, each showed a significant skew in favour of boys, while the proportion whose responses suggested they were either *very* or *somewhat* confident decreased significantly from 2019. Clearly, while average performance is encouraging, there is much to be done to understand and address the issues exposed.

Jennie Golding
Associate Professor, UCL IoE

MATHEMATICS POLICY DIGEST

Mathematicians' Open Letter on Cuts at Cardiff University

Almost 3,000 mathematicians from across the world, including 17 Fields Medallists, two Nobel Prize winners and more than 50 Fellows of the Royal Society, have written an open letter calling on Cardiff University to reverse its plans for compulsory redundancies for staff in its School of Mathematics.

Cardiff is aiming to reduce its academic maths staff from 30 to between 15 and 20 as part of its proposals, which will cut 400 academic jobs across the university as a whole.[2]

The open letter, coordinated by the Campaign for Mathematical Sciences (CaMS), warns that the move "looks like the beginning of the end of pure and applied mathematics research and teaching at Cardiff".

The letter was reported by *The Times* and *Times Higher Education*. Professor Jens Marklof, LMS President and Chair of CaMS, said:

> The response to our letter by the international community, including many of world's top academics, has been stunning. It is very rare for us to send an open letter, but the situation in Cardiff is so dramatic that we saw no other option. Cardiff University is facing a significant budget shortfall and also has ambitions to become a global top 100 university. But threatening staff in its successful School of Mathematics, which is returning a significant budget surplus and is one of its crown jewels in research, is bizarre. This will not improve Cardiff's finances nor its global reputation.
>
> The threat of compulsory redundancy means its best staff will leave first, and the university will struggle to recruit top talent in the future. Downsizing its mathematics programmes will also reduce the pipeline of desperately needed mathematics teachers going into Welsh schools.

Read the letter in full at tinyurl.com/ywdm47yw.

Digest prepared by Katherine Wright LMS
Communications and Policy Manager

Note: Items included in the Mathematics Policy Digest are not necessarily endorsed by the Editorial Board or the LMS.

[2]www.timeshighereducation.com/news/cardiff-set-cut-student-enrolment-and-increase-class-sizes

OPPORTUNITIES

2025 Fermat Prize

Nominations are now open for the 2025 Fermat Prize.

Awarded every two years by the Institute of Mathematics of Toulouse, France, the Fermat Prize rewards research work in mathematics at the highest international level in areas where Pierre de Fermat's contributions have been decisive:

- Statements of variational principles or, more generally, partial differential equations
- Foundations of probability and analytical geometry
- Number theory

Nominations are now invited. For more details, please follow the link: www.math.univ-toulouse.fr/en/activites/prix-fermat/.

Application deadline: 30 June 2025

Katherine Wright
Communications and Policy Manager

LMS Grant Schemes

Applicants for LMS grants should be mathematicians based in the UK, the Isle of Man or the Channel Islands. For grants to support conferences or workshops, the event must be held in the UK, the Isle of Man or the Channel Islands.

Research Grants

Next application deadline: 15 September 2025 (30 September 2025 for Scheme 3)

Scheme 1 — Conference and Workshop Grant

Grants of up to £5,500 are available to provide partial support for conferences and workshops. This includes travel, accommodation and subsistence expenses for principal speakers, UK-based research students, participants from Scheme 5 countries and the caring costs for attendees who have dependants.

Scheme 2 — Visitors to the UK Grant

Grants of up to £1,500 are available to provide partial support for a visitor who will give lectures in at least three separate institutions. Awards are made to the host towards the travel, accommodation and subsistence costs of the visitor. Potential applicants should note that it is expected that the host institutions will contribute to the costs of the visitor. In addition, the Society can offer a further amount (of up to £200) to cover the caring costs for those who have dependants.

Scheme 4 — Research in Pairs Grant

For those mathematicians inviting a collaborator, grants of up to £1,200 are available to support a visit for collaborative research, either by the grant holder to another institution abroad or by a named mathematician from abroad to the home base of the grant holder. For those mathematicians collaborating with another UK-based mathematician, grants of up to £600 are available to support a visit for collaborative research, either by the grant holder to another institution or by a named mathematician to the home base of the grant holder. In addition, the Society can offer a further amount (of up to £200) to cover the caring costs for those who have dependants.

Scheme 4 — Research Reboot Grant

Grants of up to £500 for accommodation, subsistence and travel plus an additional £500 for caring costs are available to assist UK mathematicians who may have found themselves with very little time for research due to illness, caring responsibilities, increased teaching or administrative loads, or other factors. This scheme offers funding so that they can leave their usual environment to focus entirely on research for a period from two days to a week.

Scheme 5 — Collaborations with Developing Countries

For mathematicians inviting a collaborator to the UK, grants of up to £3,000 are available to support a visit for collaborative research by a named mathematician from a country in which mathematics could be considered to be in a disadvantaged position to the home base of the grant holder. For mathematicians going to their collaborator's institution, grants of up to £2,000 are available to support a visit for collaborative research by the grant holder to a country in which mathematics could be considered to be in a disadvantaged position. Applicants will be expected to explain in their application why the proposed country fits the circumstances considered eligible for Scheme 5 funding. In addition, the Society can offer a further amount (of up to £200) to cover the caring costs for those who have dependants.

Contact the Grants Team if you are unsure whether the proposed country is eligible or check the IMU's Commission for Developing Countries definition of developing countries (tinyurl.com/y9dw364o).

Mathematics in Africa Grant

Grants of up to £2,000 are available to provide partial support for mathematical activities based in Africa, including attending a conference or workshop, organising a conference or workshop, or undertaking a mathematical research collaboration.

Early Career Research Grants

Next application deadline: 15 October 2025

Scheme 8 — Postgraduate Conference Grant

Grants of up to £2,500 are available to provide partial support for conferences that are organised by and are aimed at postgraduate research students. The grant award will be used to cover the costs of participants. In addition, the Society allows the use of the grant to cover to cover caring costs for those who have dependants.

Scheme 9 — Celebrating New Appointments Grant

Grants of up to £500 are available to provide partial support for meetings to celebrate the new appointment of a lecturer at a university. It is expected that the grant holder will be one of the speakers at the meeting. In addition, the Society allows the use of the grant to cover caring costs for those who have dependants.

Early Career Researcher Travel Grants

Grants of up £500 are available to provide partial travel or accommodation support for UK-based early career researchers attending conferences or undertaking research visits, either in the UK or overseas.

Lucy Covington
Grants Administrator

LMS Invited Lectures Series 2026

Call for Proposals

Proposals are invited from members and their departments to host the next *LMS Invited Lecture Series* in 2026. This lecture series consists of meetings held in the UK at which a single speaker gives a course of approximately ten expository lectures that examines a selected subject in depth over five days (Monday to Friday) during a university vacation. The meetings are residential and open to all interested. Funding of up to £6,000 is offered to the host department to support the invited lecturer's costs and participants' attendance at the lectures.

Proposals for the Invited Lectures 2026

Any member who would like to suggest a topic and lecturer and be prepared to organise the meeting at their own institution or a suitable conference centre can submit a proposal. For further details, please visit the Society's website: tinyurl.com/hnrju8er.

The Society encourages nominations of mathematicians from diverse backgrounds.

Recent previous invited lecturers:

- 2024: Dan Abramovich (Brown University), *Logs and Stacks in Birational Geometry and Moduli*, Imperial College London, 1–5 July 2024
- 2023: Filippo Santambrogio (Université Lyon 1), *Optimal Transport and its Applications*, Durham University, 17–21 July 2023
- 2022 (postponed from 2021): Olga Kharlampovich (CUNY Graduate Center and Hunter College), *Equations in Groups and Complexity*, Newcastle University, 18–22 July 2022

- 2022: Gitta Kutyniok (Munich), *The Mathematics of Deep Learning*, Cambridge University, 28 February – 4 March 2022

- 2020: Yulia Mishura (University of Kyiv), *Fractional Calculus and Fractional Stochastic Calculus, including Rough-Paths, with Applications*, Zoom via Brunel University, 15–19 June 2020

Enquiries about the invited lectures may be addressed to the Chair of the Society, Lectures and Meetings Committee, Jason Lotay (lmsmeetings@lms.ac.uk).

Deadline for proposals: 1 June 2025

Nicola Goldie
Committee, Grants and Membership Manager

VISITS

Visit of Cristhian Montoya

Professor Cristhian Montoya will be visiting the University of Nottingham from 19 May to 13 June 2025. Professor Montoya is a member of the Mathematical Modelling group at Universidad EAFIT in Medellín, Colombia. His research areas include control theory, numerical analysis and inverse problems modelled by partial differential equations with applications in health sciences. During his visit, Professor Montoya will give lectures at:

- University of Nottingham, 29 May (contact Ignacio Brevis: ignacio.brevis@nottingham.ac.uk)
- Imperial College London, 12 June (contact Dante Kalise: d.kalise-balza@imperial.ac.uk)

For further details, contact Ignacio Brevis (ignacio.brevis@nottingham.ac.uk). The visit is supported by an LMS Scheme 5 grant.

Visit of Chaman Kumar

Dr Chaman Kumar will be visiting the School of Mathematical Science, University of Nottingham, from 25 May to 14 June 2025. Dr Kumar is an Associate Professor at the Department of Mathematics of the Indian Institute of Technology Roorkee, India. His research interests are mostly in stochastic numerics (studying and developing numerical methods for stochastic differential equations of various types). During his visit, Dr Kumar will collaborate with Michael Tretyakov (Nottingham) on stochastic numerics and also will give talks at Nottingham, Leeds and Oxford.

For further details, contact Prof Michael Tretyakov (Michael.Tretyakov@nottingham.ac.uk). The visit is supported by an LMS Scheme 5 grant.

Visit of Betti Hartmann

Dr Betti Hartmann will be visiting the Physics Department of St Xavier's College, Kolkata, India, from 2 to 25 April 2025. Dr Hartmann is an Associate Professor of Mathematics at University College London. Her research is centred around the (numerical) study of non-linear phenomena in classical field theory models with a focus on black holes and self-gravitating solitons. During her visit, she will collaborate with Dr Suparna Roychowdhury to study chaotic test particle motion in generalised black hole space-times. Betti Hartmann will give a scientific talk during a one-day international colloquium on 8 April 2025 at St. Xavier's College as well as an outreach talk on *Gender Equality in Science*.

The visit is supported by an LMS Scheme 5 grant.

Visit of Davide Catania

Dr Davide Catania will be visiting the Department of Mathematics, Surrey University, from 22 April to 3 May 2017. Dr Catania is a member of the Research Group of Mathematical Analysis of the University of Brescia. His recent research activity concerns partial differential equations in fluid dynamics and magnetohydrodynamics (MHD) that model physical or engineering problems. During his visit, Dr Catania will give lectures at:

- University of Sussex, 24 April (contact Gabriel Koch: G.Koch@sussex.ac.uk)
- University of Oxford, 27 April (contact Angkana Ruland: ruland@maths.ox.ac.uk)
- University of Surrey, 2 May (contact Michele Bartuccelli: m.bartuccelli@surrey.ac.uk)

For further details, contact Michele Bartuccelli (m.bartuccelli@surrey.ac.uk).

The visit is supported by an LMS Scheme 2 grant.

Visit of Narayanaswamy Balakrishnan

Professor N. Balakrishnan, a renowned statistician and Distinguished Professor at McMaster University, will visit Durham from 24 to 31 July. He has made pioneering contributions to theoretical and applied statistics, particularly in statistical inference, reliability theory, asymptotic statistics and order statistics. With an extensive career and numerous publications, he is widely recognised as a leading expert. During his visit, he will give lectures at:

- University of York, 25 July (contact Marina Knight: marina.knight@york.ac.uk)
- Newcastle University, 28 July (contact Kevin Wilson: kevin.wilson@newcastle.ac.uk)
- Durham University, 29 July (contact Tahani Coolen-Maturi: tahani.maturi@durham.ac.uk)

For further details, contact Tahani Coolen-Maturi (tahani.maturi@durham.ac.uk).

The visit is supported by an LMS Scheme 2 grant.

LMS Council Diary — A Personal View

Council met via videoconference on Friday, 7 February 2025. After a brief update from the Head of Publications on the ongoing publications tender process for the Society-owned journals, the President reported on activities related to the Campaign for Mathematical Sciences (CaMS), including meetings with several members of parliament and that the Maths Degrees for the Future grants programme had recently completed the shortlisting process having received applications from 34 universities. The President also outlined various types of support that the Society has been providing to university mathematics departments under threat, including writing letters to Vice Chancellors and Members of Parliament. Each letter was specific to the circumstances for the institution, and the President encouraged anyone aware of further problems to contact him in confidence. It was also highlighted that CaMS was playing a key role in supporting affected departments and had launched a provision tracker on its website listing news reports of threats of redundancies. Moreover, EPSRC has now restarted its fellowships in mathematical sciences after having paused fellowships in all subjects last December.

Council then discussed the upcoming Council Strategic Retreat, which will take place in April, and received an update from the Executive Secretary on the maintenance programme for De Morgan House, including the installation of an outdoor lift. LMS staff had attended the Joint Mathematical Meeting in Seattle in January 2025, and the LMS has started to work with a fundraising consultant. After hearing from Vice-President Gordon on the development of the Academy for Mathematical Sciences, the Treasurer presented the First Quarter Accounts Review and Budget Revision, and Council approved bids to the Strategic Development Fund for the financial year 2024/25.

Following discussion of a paper introduced by the International Secretary, Council agreed to establish the Global Affairs Committee, which will build on the activities of the Global Engagement Working Group over the last year. Council then had a wide-ranging discussion on the Committee for Women and Diversity LMS Prizes Report, which highlighted issues with diversity and proposed a review of LMS prizes, and approved preparation of a further paper. Other business included the Scrutineers Report on the LMS 2024 elections, various issues regarding committee membership and the Membership Census 2025 report.

The meeting concluded with the President thanking everyone for their contributions.

Elaine Crooks
Member-At-Large

Annual Elections to LMS Council

The LMS Nominating Committee is responsible for proposing slates of candidates for vacancies on the Council and vacancies on the Nominating Committee itself. The Nominating Committee welcomes suggestions from the membership.

Anyone who wishes to suggest someone for a position as an Officer of the Society or as a Member-at-Large of the Council (now or in the future) is invited to send their suggestions to Professor Helen Wilson, the current Chair of the Nominating Committee (nominations@lms.ac.uk). Please provide the name and institution (if applicable) of the suggested nominee, their mathematical specialism(s) and a brief statement explaining what they could bring to the Council or Nominating Committee.

It is to the benefit of the Society that the Council is balanced and represents the full breadth of the mathematics community; to this end, the Nominating Committee aims for a balance in gender, subject area and geographical location in its list of prospective nominees.

Nominations should be received by 16 May 2025 if they are to be considered by the Nominating Committee.

In addition to the above, members may make direct nominations for election to the Council or the Nominating Committee. Direct nominations must be sent to the Executive Secretary's office (nominations@lms.ac.uk) before noon on 1 September 2025. For details about making a direct nomination, see lms.ac.uk/about/council/lms-elections.

The slate as proposed by the Nominating Committee, together with any direct nominations received up to that time, will be posted on the LMS website in early August.

Simon Edwards
LMS Executive Secretary (CEO)

Maximising Your Membership: Free Online Journal Access and Books Discounts

Membership of the London Mathematical Society offers a wealth of benefits that support the professional and academic growth of mathematicians, such as access to high-quality peer-reviewed papers in a growing collection of esteemed journals. The portfolio published by the Society now comprises nine well-regarded titles, and members of the LMS can enjoy free online subscriptions to the five journals listed below.

Free online access to LMS Journals

The *Proceedings of the London Mathematical Society* is the Society's flagship, and its highest impact, peer-reviewed journal. Published since 1865, the *Proceedings* publishes articles of the highest quality and significance across a broad range of mathematics. There are no page length restrictions for submitted papers.

The *Bulletin of the London Mathematical Society* has been publishing leading research across a broad range of mathematics since 1969. The *Bulletin* focuses on concise articles reporting a significant advance in mathematical knowledge as well as articles that will stimulate new interest and research activity. The articles have a maximum length of 20 pages and may be of specialist or general interest. In addition to primary research articles, the *Bulletin* also publishes authoritative survey articles (of any length) and obituaries.

The *Journal of the London Mathematical Society* has been publishing leading research across a broad range of mathematics since 1926. Articles published in the *Journal* should describe a significant advance in mathematical knowledge, or they should stimulate new interest and research activity. With a minimum length of 18 pages and no maximum length, articles in the *Journal* may be of specialist or general interest.

The *Journal of Topology* publishes papers of high quality and significance in topology, geometry and adjacent areas of mathematics. Interesting, important and often unexpected links connect topology and geometry with many other parts of mathematics. The Editors of the *Journal of Topology* welcome submissions on exciting new advances concerning such links as well as those in the core subject areas of the journal.

The *Transactions of the London Mathematical Society* is the gold open access journal of the London Mathematical Society. Publishing high-quality articles across the full range of mathematics, the *Transactions* places an emphasis on the excellent exposition of research that explores the interconnectedness of pure mathematics or extends the boundaries of its applicability.

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Mathematika, published by the LMS on behalf of UCL, features both pure and applied mathematical articles while maintaining a traditional emphasis on pure mathematics since its founding in the 1950s.

Members can sign up to gain free online access to any or all of these titles by registering their interest in their LMS user record through lms.ac.uk/user or by returning a completed subscription form by post to LMS Membership, De Morgan House, Russell Square, London, WC1B 4HS, UK.

Open Access Options

The LMS supports open access publishing, which means that members can publish their work in a way that is freely accessible to the global mathematical community. The *Transactions of the London Mathematical Society* is the Society's fully open access journal. It explores the interconnectedness of pure mathematics and its applicability.

Book discounts

The Society's members can receive a 25% discount on books in the *LMS Lecture Notes* and *LMS Student Texts* Series. The *LMS Lecture Notes* provides valuable information for mathematicians and researchers through short monographs and conference proceedings that cover a wide range of mathematical topics. The *LMS Student Texts* are textbooks for undergraduates and beginning graduate students, covering pure and applied mathematics, as well as mathematical physics, to help non-specialists and students understand modern mathematical methods.

All publications from these book series are available to individual members at a discounted price when ordered directly from the Cambridge University Press website. The discount codes and other exciting news about the Society's activities and events are sent to all members in our monthly *eUpdates*.

Ethical Publishing Standards

The LMS adheres to strict ethical guidelines for its publications to ensure that the research published is of the highest quality and integrity. This commitment to ethical standards helps maintain the credibility and reliability of the research disseminated through LMS journals.

Collaborative Opportunities in Mathematics with the LMS

By accessing the latest research and developments published in LMS journals, members can identify and connect with mathematicians who share similar interests, thus fostering fruitful collaborations and the exchange of ideas. This not only advances mathematical knowledge but also helps in developing cutting-edge research and identifying new opportunities. To enhance academic communication, members can choose to publish their research work in LMS journals. This allows them to reach an international audience, which increases the visibility and impact of their work. Every article published in LMS journals generates funding for the Society, which is entirely reinvested in mathematics and further supports the community and its research.

To find out more about LMS publications, please visit our website: lms.ac.uk/publications.

Valeriya Kolesnykova
Fellowships, Membership and Accounts Assistant

REPORTS OF THE LMS

Report: My Experience at AGGITatE 2024

As a first-year PhD student, attending AGGITatE 2024 was a valuable learning experience. It gave me opportunities to dive deeper into a number of concepts that I had only recently been introduced to, and the lectures provided through the school helped me to consolidate many of these ideas and introduced me to new ones that I could explore further. The whole environment was really helpful and gave me the chance to speak to top researchers in my field, which has helped me to build my network.

Here are a few of my highlights.

Kristin DeVleming talked about wall crossings for moduli spaces of varieties. These were very well explained and presented at a level accessible to all in the audience.

Victoria Hoskin's lectures on non-reductive geometric invariant theory were incredibly useful to my research. I particularly liked the way she explained the issues that non-reductive groups create as opposed to reductive groups.

Chenyang Xu's talks on K-moduli of Fano varieties were an in-depth outline of past and recent research in K-moduli. They provided a good foundation on this subject and were based on the soon-to-be-published book on K-stability of Fano varieties.

Jarod Alper's lectures on geometric invariant theory and good moduli spaces led to the creation of an online reading group for his book *Stacks and Moduli*. This will be hugely beneficial to both my own PhD as well as those of the other participants', as the group enables us to discuss any problems or questions that we may face when reading this book that otherwise might have gone unresolved.

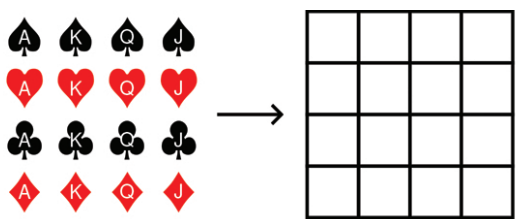
Charlotte Satchwell

Latin Squares via Graph Theory

RICHARD MONTGOMERY

Latin squares are one of the oldest combinatorial objects and have been studied throughout the modern history of combinatorics. More recently, much has been revealed by considering them from the perspective of graph theory.

Here is a puzzle designed to while away part of a winter's evening in the early 18th century. Take all the aces, kings, queens and jacks of a standard deck of cards. Can you arrange these 16 cards into a 4×4 grid so that each row and each column contains an ace, king, queen and jack from different suits?



It is hard to avoid immediately revealing that the answer to this is 'yes', although we only depict this overleaf. In fact, there are two non-isomorphic solutions, which cannot be transformed into each other by exchanging pairs of rows, columns, suits or card values.

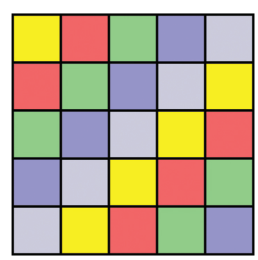
More challenging than the card problem is one that purportedly did the rounds at the court of Catherine the Great, and is now known as Euler's 36 officers problem. If there are six regiments, each having six officers of six different ranks, can these 36 officers stand in a grid so that each row and column has one officer from each rank and one officer from each regiment? That is, is it possible to generalise the $n = 4$ card problem to $n = 6$? For example, on the right is a solution for the $n = 5$ version with five regiments (chess pieces) and five ranks (colours).

To state these two problems in full generality, we use Latin squares. A Latin square of order n is an $n \times n$ grid filled with n symbols, so that each symbol appears exactly once in each row and each column. They have a long history in recreational mathematics, in part due to a strong connection with magic squares. More recently, such grids have become very familiar to many as the underlying grid of Sudoku puzzles, the solutions to which are Latin squares of order 9 (which also satisfy some conditions on some 3×3 subsquares).

1	8	7	9	3	5	2	4	6
4	2	5	7	6	8	1	3	9
6	9	3	4	1	2	7	5	8
2	3	1	5	8	9	4	6	7
5	6	9	1	4	7	8	2	3
7	4	8	3	2	6	5	9	1
8	1	2	6	9	4	3	7	5
3	5	6	2	7	1	9	8	4
9	7	4	8	5	3	6	1	2

Important examples of Latin squares include the Cayley tables of groups, where after indexing the rows and columns by some group G of order n, the symbol allocated to each cell is the product of its row with its column. Latin squares have strong connections to design theory and error correcting codes, as well a long history of study in their own right as a combinatorial object.

To return to the 36 officers problem, our solution to the $n = 5$ case can be seen to contain two Latin squares of order 5. Forgetting the colours, we get a Latin square using the chess pieces. Forgetting the chess pieces, we get a Latin square using the colours:



These two Latin squares are *orthogonal*: that is, they are two Latin squares of order n, where taking the pairs of symbols in corresponding cells gives all n^2 possible pairs. This is inherent in the 36 officers problem: we have an officer satisfying every possible combination of rank and regiment. The problem, then, is equivalent to asking: is there a pair of orthogonal Latin squares of order 6?

Euler could find no solution to this problem and conjectured that no such solution exists. Moreover, he found orthogonal Latin squares of order n for each $n \not\equiv 2 \bmod 4$ and conjectured that otherwise they do not exist.

Conjecture 1 (Euler, 1782). If $n \equiv 2 \bmod 4$, then there are no orthogonal Latin squares of order n.

Examples of orthogonal Latin squares of order n when $n \not\equiv 2 \bmod 4$ are easiest to see when n is odd, in particular using an equivalent formulation using *transversals*.

Transversals

In a Latin square of order n, a transversal is a collection of n cells that share no row, column or symbol. An example is highlighted in colour in the Latin square of order 6 below to the left.

1	4	6	5	3	2
5	2	4	3	1	6
6	3	2	4	5	1
2	5	1	6	4	3
3	6	5	1	2	4
4	1	3	2	6	5

Given two orthogonal Latin squares of order n, each set of cells with the same symbol in one of the Latin squares marks out a transversal in the other. Thus, each Latin square marks out in its orthogonal pair a set of n transversals that overlap on no cells, giving what we call a decomposition into transversals. There is a pair of orthogonal Latin squares of order n exactly if there is a Latin square of order n with a decomposition into transversals.

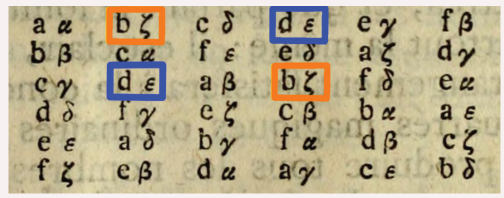
Let G be a group of order n and suppose that its Cayley table has a transversal T. That is, we can label the different elements of G as h_g, $g \in G$, so that $T = \{(g, h_g) : g \in G\}$ and $g \circ h_g$ is distinct over $g \in G$. Then, $\{(g, h \circ h_g) : g \in G\}$ can be seen to be a transversal for each $h \in G$, and these transversals are all disjoint. Thus, the Cayley table for G has a decomposition into transversals if and only if it has any transversal.

0	1	2	3	4	5	6
1	2	3	4	5	6	0
2	3	4	5	6	0	1
3	4	5	6	0	1	2
4	5	6	0	1	2	3
5	6	0	1	2	3	4
6	0	1	2	3	4	5

For any group G of odd order, the leading diagonal of its Cayley table (i.e., $\{(g, g) : g \in G\}$) is a transversal as the function $g \mapsto g \circ g$ permutes the elements of the group. Thus, this gives an easy route to orthogonal Latin squares of order n whenever n is odd. When $n \equiv 0 \bmod 4$, showing that there are orthogonal Latin squares of order n is a little more difficult. However, for example, Paige determined which Cayley tables of abelian groups have a transversal in the 1950s, and applying this shows that the Cayley table for $\mathbb{Z}_2^2 \times \mathbb{Z}_m$ has a transversal for each $m \in \mathbb{N}$.

A near solution for $n = 6$

In his 1782 paper, Euler came close to a solution to his 36 officers problem, depicting two Latin squares of order 6 together, one using Latin letters and the other using Greek letters:



a α	b ζ	c δ	d ε	e γ	f β
b β	c α	f ε	e δ	a ζ	d γ
c γ	d ε	a β	b ζ	f δ	e α
d δ	f γ	e ζ	c β	b α	a ε
e ε	a δ	b γ	f α	d β	c ζ
f ζ	e β	d α	a γ	c ε	b δ

As Euler pointed out, these are not orthogonal Latin squares as (d, ε) and (b, ζ) both appear twice, while (b, ε) and (d, ζ) appear no times. Euler's notation here gave rise to the name 'Latin square', while orthogonal Latin squares are also known as Greco-Latin squares.

For non-abelian groups G in general, whether or not the Cayley table of G has a transversal is a difficult question, but is now known to be equivalent to a condition on the 2-Sylow subgroups of G. This was the subject of the Hall–Paige conjecture in the 1950s, which was confirmed only in 2009, by a combination of work by Bray, Wilcox and Evans that relies on the classification of finite simple groups.

Implicit in our discussion so far is a simple fact: not every Latin square has a transversal. However, the only known examples have even order. The canonical examples of Latin squares without transversals for each possible even order are the Cayley tables for $\mathbb{Z}_{2m}$, $m \in \mathbb{N}$. To see this, suppose for contradiction that $\{(g, h_g) : g \in \mathbb{Z}_{2m}\}$ is a transversal in the Cayley table for $\mathbb{Z}_{2m}$, with $m \in \mathbb{N}$, which by definition has $g + h_g$ in the cell (g, h_g) for each $g \in G$. Then, as the functions $g \mapsto g$, $g \mapsto h_g$ and $g \mapsto g + h_g$ range over the elements of $\mathbb{Z}_{2m}$, we have

$$\sum_{g \in \mathbb{Z}_{2m}} g + \sum_{g \in \mathbb{Z}_{2m}} g = \sum_{g \in \mathbb{Z}_{2m}} (g + h_g) = \sum_{g \in \mathbb{Z}_{2m}} g,$$

and thus, $\sum_{g \in \mathbb{Z}_{2m}} g = 0$. As $\sum_{i=1}^{2m} i = m(2m-1) = m \bmod 2m$ implies that $\sum_{g \in \mathbb{Z}_{2m}} g = m$, we arrive at a contradiction. Therefore, no transversal exists.

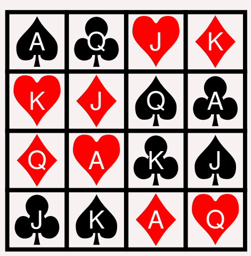
In 1967, Ryser conjectured that Latin squares with no transversal can exist only if they have even order. Given a Latin square, how close can we get to a transversal? A partial transversal in a Latin square is a collection of cells that share no row, column or symbol. An example is given on the right in the Cayley table for $\mathbb{Z}_6$. A fundamental aim of extremal combinatorics is to investigate the most extreme behaviour among a collection of combinatorial objects. The natural question here is this: how small can a largest partial transversal be in a Latin square of order n? Brualdi conjectured that it cannot be smaller than $n-1$. Combined with Ryser's conjecture and reflecting related conjectures by Stein, this has become widely known as the Ryser–Brualdi–Stein conjecture in the following form.

0	1	2	3	4	5
1	2	3	4	5	0
2	3	4	5	0	1
3	4	5	0	1	2
4	5	0	1	2	3
5	0	1	2	3	4

Conjecture 2. Any Latin square of order n has a partial transversal with $n-1$ cells and a transversal if n is odd.

A solution for $n = 4$

An arrangement of 16 cards, with one ace, king, queen and jack from different suits in each row and column. The second, non-isomorphic, solution is not pictured.



Settling Conjecture 1

Euler's conjecture is easy to confirm for $n = 2$, for there is (up to isomorphism) exactly one Latin square of order 2. Finally confirming that there is no solution to the 36 officers problem is a much sterner task. This was eventually accomplished by Tarry in 1900, via exhaustion (and a little sensible reduction to key cases). Conjecture 1, then, is true for $n = 6$.

Euler's conjecture saw some notable false proofs in the first half of the 20th century, some of which took years to disprove. This likely reflects an expectation that the conjecture was true, which must have made the following flurry of activity in 1959 rather surprising! First, Bose and Shrikhande disproved Conjecture 1 by giving a counterexample with $n = 22$. Inspired by this, Parker then showed that it is not even true for $n = 10$, giving a counterexample found in a very early example of a computer-assisted proof. Finally, Bose, Parker and Shrikhande combined forces to construct counterexamples that show that the conjecture is false for every $n \geq 10$ with $n \equiv 2 \bmod 4$. The disproof of Euler's conjecture was sufficiently significant to appear on the front page of the *New York Times* (albeit below the fold!), which announced that a 'Major Mathematical Conjecture Propounded 177 Years Ago Is Disproved'.

0	6	5	4	9	8	7	1	2	3
7	1	0	6	5	9	8	2	3	4
8	7	2	1	0	6	9	3	4	5
9	8	7	3	2	1	0	4	5	6
1	9	8	7	4	3	2	5	6	0
3	2	9	8	7	5	4	6	0	1
5	4	3	9	8	7	6	0	1	2
2	3	4	5	6	0	1	7	8	9
4	5	6	0	1	2	3	8	9	7
6	0	1	2	3	4	5	9	7	8

Figure 1: Parker's counterexample for $n = 10$

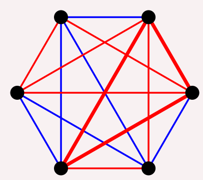
This could have been the end of the road for Conjecture 1, but developments in combinatorics shortly before had led to the creation of 'the probabilistic method', which points to an intriguing possibility. In cooking up their counterexamples, Bose, Parker and Shrikhande took great care to construct Latin squares that had a decomposition into transversals (or, in other words, an orthogonal pair). What if such care were unneeded? If we blithely grabbed a Latin square of order n without thinking, is it likely to have a decomposition into transversals?

The probabilistic method

The essence of the probabilistic method is beguilingly simple and belies its true power. You wish to prove the existence of a structure with a certain desirable property (like a Latin square with a decomposition into transversals). Suppose you can find a probability distribution such that if you draw the structure according to this distribution, then with strictly positive probability, it will have this desirable property. Then, you can inescapably conclude there must exist a structure with the property you want!

This is best seen in practice. The following example from 1947 is due to Erdős, who pioneered the use of the probabilistic method. For each n (and as shown to exist by Ramsey in 1929), the Ramsey number $R(n)$ is the least N such that if we take N vertices with every possible edge between them (the complete N-vertex graph), then, if each edge is coloured red or blue, we can always find within this a complete n-vertex graph whose edges are all red or are all blue. However disordered the colouring may seem, a little order can found. Here, the central question is a quantitative one: what is the asymptotic behaviour of $R(n)$?

Bounds on small Ramsey numbers



If the edges of the complete graph with six vertices are coloured red and blue, then there will always be a red triangle or a blue triangle (here, a red triangle). For five vertices, there are colourings with no such monochromatic triangle, and therefore $R(3) = 6$. We know that $R(4) = 18$, but $R(5)$ is unknown, and was only recently narrowed down to four possible values, by Angeltveit and McKay, with substantial computer assistance.

As Erdős showed, if we take the complete graph on $N = \lfloor (\sqrt{2})^n \rfloor$ vertices and colour each edge red or blue independently at random with equal probability, then with strictly positive probability, there is no set of n vertices between which either all the edges are red or all the edges are blue. Thus, there must be some red/blue edge-colouring of the complete graph with N vertices with no red or blue n-vertex complete subgraph, and so $R(n) > N$.

Combining this with an upper bound due to Erdős and Szekeres in 1935, we get (in slightly simplified terms) that

$$\left(\sqrt{2}\right)^n \leq R(n) \leq 4^n.$$

Can you improve either $\sqrt{2}$ or 4 here, perhaps at least for large n? It would be hard to underestimate the collective amount of time that has been spent on this question, which is so easily defined! Many years passed in which the only fruits of this labour were modest sub-exponential improvements. Only in 2023 was it shown that 4 could be nudged to some constant a little lower, when n is large, in truly remarkable work by Campos, Griffiths, Morris and Sahasrabudhe [4]. Erdős's lower bound, however, has still seen only very slight improvement, in which the probabilistic method continues to reign supreme.

The probabilistic method sets up a very strong connection between extremal combinatorics and probabilistic combinatorics. As mentioned, in the former, we typically consider a set of combinatorial objects and wish to know the extreme behaviours that occur; in the latter, we usually wish to ignore the extremes and study instead the behaviour of a typical member of the set. For example, a graph with $2n$ vertices and n^2 edges may have no triangles, but if we pick such a graph randomly, we should expect it to have around $n^2/6$ triangles!

Can we use the probabilistic method to disprove Conjecture 1? Might it even be true that if we pick a Latin square uniformly at random, then it will be very likely to have a decomposition into transversals? To do this, we will need to define precisely a uniformly random Latin square and then study its properties, but something of a wrinkle arises: how should we study a random Latin square?

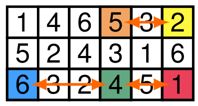
Random Latin squares

Consider the following most natural choice for a random Latin square. For each n, let $\mathcal{L}_n$ be the set of Latin squares of order n using the symbols in $\{1, 2, \ldots, n\}$. Uniformly at random, pick $L_n \in \mathcal{L}_n$. How should we study the likely properties of L_n?

This is challenging, seemingly because of the rigidity of Latin squares due to the restrictive conditions in their definition. From simple heuristics (which are surprisingly hard to confirm!), we can expect to be able to make small adjustments in most Latin squares to reach another Latin square. For example, on the right is a Latin square in which the symbols in the coloured cells (which form an 'intercalate') can be permuted to give another Latin square. However, in practice, the number of ways in which we can do this is usually too small to be of much use.

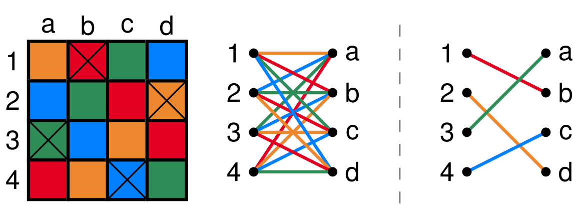
1	4	6	5	3	2
5	2	4	3	1	6
6	3	2	4	5	1
2	5	1	6	4	3
3	6	5	1	2	4
4	1	3	2	6	5

Less rigid, are *Latin rectangles*. A $k \times n$ Latin rectangle is a $k \times n$ grid filled with n symbols such that no symbol appears more than once in any row or column. In the 3×6 Latin rectangle pictured, there are many pairs of cells that can be swapped to get another Latin rectangle, many more even than the three swaps indicated by arrows. The presence, in general, of so many swaps (when $k \leq n/2$, say) means that we can use what are known as switching methods, which makes it much easier to study a uniformly random $k \times n$ Latin rectangle than a uniformly random Latin square of order n (which has no such direct swaps). Results on properties of random Latin rectangles that hold with probability very close to 1 can then be translated to properties that hold in random Latin squares with probability still close to 1, as shown by McKay and Wanless. This translation uses an equivalence of Latin squares with certain graphs, which allows the application of graph theoretic tools.



The graph theoretic perspective

A Latin square of order n (using colours for symbols) is equivalent to a properly coloured complete bipartite graph, as follows (and as depicted below). Create a vertex for each row and for each column. For each row and column pair, put an edge between the corresponding vertices, and colour it with the colour of the cell with that row and column.



In the resulting graph, the edges are coloured with n colours so that no two edges of the same colour meet at any vertex. This is known as a *proper* colouring using n colours. A transversal has a natural equivalence in this graph form: it is a set of n edges that share no vertices or colours and is known as a perfect rainbow matching. In the figure above, the transversal marked out by crosses on the left is drawn as a perfect rainbow matching on the right.

This equivalence allows us to bring to bear the many tools of modern graph theory to Latin squares. For example, for more than 40 years, essentially the best possible bound towards Conjecture 2 was one by Shor (a proof latterly corrected by Hatami and Shor), namely that every Latin square of order n has a partial transversal with $n - O(\log^2 n)$ cells. Using graph theoretic techniques, this bound was finally improved in 2020 by Keevash, Pokrovskiy, Sudakov and Yepremyan, who reduced the $O(\log^2 n)$ term to $O(\log n / \log\log n)$. In 2023, I managed further progress by showing that, if n is sufficiently large, then every Latin square of order n has a partial transversal with $n - 1$ cells.

To go back to Conjecture 1 one last time, we asked whether a random Latin square of order n is likely to have a decomposition into transversals. Candida Bowtell and I very recently confirmed that this is true [3]! Thus, the proportion of Latin squares of order $n \equiv 2 \bmod 4$ that have an orthogonal pair, and therefore disprove Conjecture 1, tends to 1 as n tends to infinity. This result was possible only with graph theory tools, whose application has reinvigorated the long study of Latin squares.

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Richard Montgomery

Richard Montgomery is an Associate Professor at the University of Warwick whose research is in extremal and probabilistic combinatorics.

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Primary School Mathematics Puzzles and Games Club

PETER ROWLETT AND GWILYM JONES

We set up a Key Stage 2 Maths Puzzles and Games Club at a Primary School in Nottingham. The focus on puzzles and games allowed us to expose the children to a playful and creative side of mathematics, which allowed them to explore patterns and develop their logical and strategic thinking. This article describes the context and shares some activities from the club.

Introduction

Key Stage 2 (ages 7 to 11) is an educational stage during which pupils learn mathematics more formally and less playfully than they might have previously. With an increased focus on arithmetic methods and correct answers, some can start to lose enthusiasm and confidence, a problem that develops through secondary school. We aimed to enhance and enrich mathematical study beyond the curriculum by creating and delivering a new after-school maths club themed around puzzles and games with a playful and creative focus.

Context

Our club was based at Middleton Primary and Nursery School in Nottingham in spring term 2024. One of us (G.J.) is a teacher and maths coordinator at the school and the other (P.R.) is an academic mathematician and parent of a child at the school. We were fortunate to receive £500 via an LMS Small Education Grant to buy equipment to set up the club. The running costs were met by the school, and we volunteered our time.

The school has an established after-school programme with clubs for various sports (e.g., football, running and dodgeball) as well as yoga, dance, arts and crafts, and music.

We targeted years 4 and 5 in an attempt to grow enthusiasm for a broader view of mathematics as a creative and playful discipline by exposing pupils to aspects of mathematical thinking and to links to art and creativity that they may not experience in the formal curriculum.

After-school clubs are traditionally offered to all parents simultaneously. If we had used this approach, the places would likely have been taken up by pupils who enjoy maths and are confident with it. To expand the activity to address a new, wider audience, we reserved half the places for targeted students. These places were offered for free to pupils who are eligible for pupil premium and to those identified by teachers. Teachers were asked to identify pupils whom they felt would especially benefit from taking part, including those who were struggling with confidence in maths, a problem particularly observed with girls in these year groups, and those who were struggling with cooperating or taking turns.

Sessions

Our Maths Puzzles and Games Club met for one hour after school weekly for half a term. This meant five sessions took place, with one week when clubs didn't run because of parents' evening. We have chosen an example activity from each section to give an idea of what happened at the club.

Noughts and crosses

Children this age have usually played noughts and crosses and some have a reliable strategy for winning. The standard game is a draw when both players play optimally. When told that this had been proven using mathematical logic, several children gasped! In this session, we played some variant rule sets designed to keep things interesting while exercising their strategic thinking skills.

An analysis of noughts and crosses relies on this being a finite game with no random chance, that players take turns so that everyone can make their optimal move and that O follows X (and vice versa). A fun game that breaks these assumptions was sold in the 1970s as Ox Blocks. In this version, one player tries to get three X's in a row and the other tries to get three O's in a row as usual, but a die is used to determine what the player must do in their turn. In the commercial version, a custom die is used with O's, X's and blank sides, but this can be simulated using a standard die. Each turn, a player rolls a die and applies the following rules.

- If you roll ⚀ or ⚅, you must place an X on the board (even if you are playing as noughts).
- If you roll ⚁ or ⚄, you must place an O on the board (even if you are playing as crosses).
- If you roll ⚂ or ⚃, you must remove a symbol from the board (even if there are only your symbols there). If there are no symbols on the board, do nothing this turn.

Mathematical magic

There are many so-called self-working magic tricks that rely on mathematical principles. Often these hide their mathematics in card magic, memorisation tricks or mind-reading displays. In this session, the children learned several tricks that they tried on each other and as a whole group activity.

A famous trick involves a series of cards listing numbers. You ask someone to choose a number and then tell you on which cards it appears. Quickly, you 'read their mind' and tell them their number. In practice, you do this by summing the first number on all the cards they name. The way this works uses binary numbers, with each card representing a bit: 1 if the number appears and 0 if it does not. For example, since $11 = 1 + 2 + 8$, its binary representation is 1011. This corresponds to cards 0, 1 and 3, so 11 appears only on these cards. Numbers for a set of four cards are provided below; of course the trick can be extended to larger numbers of bits.

Card 0:	1	3	5	7	9	11	13	15
Card 1:	2	3	6	7	10	11	14	15
Card 2:	4	5	6	7	12	13	14	15
Card 3:	8	9	10	11	12	13	14	15

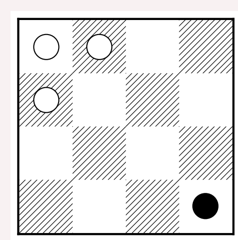
Games on chessboards

We avoided chess, which is quite a complicated game for our needs, although the school does run a lunchtime chess club. Lots of puzzles use a chessboard. For example, the n-queens problem asks for the placement of n queens on a chessboard such that none of them can attack another. We gave this in the form: "Place 4 counters on a 4 × 4 section of a chessboard so that no two are on the same row, column or diagonal." We challenged the quicker children to try with larger n.

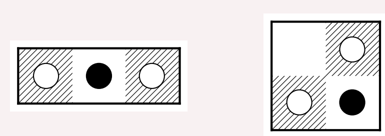
We also chose to play two-player strategy games that use chessboards and pieces and which demonstrate different game mechanics. For a chess-like game, we chose hexapawn, and for a halma game, we played grasshopper. For a *tafl* game, we invented 'cops and robbers' (see box), which, for this age group, has the added bonus that the players need to keep a tally or otherwise record data about the number of moves.

Cops and robbers

Play on a 4 × 4 grid. Two players take turns. The cops are three white draughts pieces starting in the top left. The robber is a black draughts piece starting in the bottom right. All pieces can move one space up, down, left or right, but not diagonally.



Choose who will play as the cops and who will control the robber. The cops move first. The cops capture the robber by surrounding them, either with two cops arranged on opposite sides or, if the robber is in the corner, by trapping them there.



Play until the cops catch the robber, then swap roles and play again. The winner is whoever caught the robber the quickest, so keep count of how many moves you play!

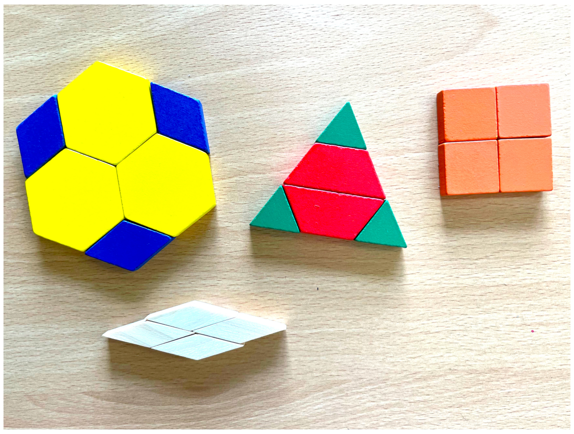


Figure 1. One child's response to the puzzle of creating larger versions of the pattern block shapes

Figure 2. Creative play with pattern blocks and magnetic tiles

Patterns and shapes

We used six wooden tiles: equilateral triangles, squares, hexagons, trapezia, and 60° and 30° rhombi. These were designed with many shared lengths so they can be tiled in lots of different ways. They are pleasingly meditative to manipulate, and we used them for puzzles that involved copying patterns and extending them to add a creative element to this mathematical play.

One puzzle was to create larger versions of the tiles using the tiles themselves; one child's response to this prompt is shown in Fig. 1. Another task involved copying a central pattern and then extending it however the children liked. Each child was given a set of pattern blocks, but they were encouraged to work with others to produce larger patterns.

In this session, we also introduced magnetic tiles for building polyhedra and other models. Children were given a set of squares and triangles in small groups and worked together on construction activities. In both activities, we allowed time for creative play. Some of the children's creations are shown in Fig. 2.

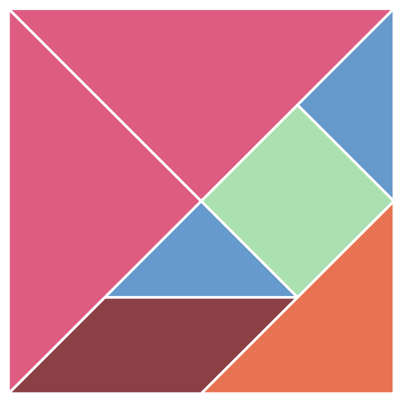


Figure 3. Tangrams

Tangrams

Tangrams are a dissection of a square into seven pieces, as shown in Fig. 3. The pieces are known as tans. Traditionally, the challenge is to reproduce a shape with tans given only its outline. For this age group, we focused first on accurately copying shapes when the gaps between tans can be seen, as in Fig. 4. We later provided a sheet of problems that had a version without gaps on one side and a version with gaps on the other, so that the children could choose the level of challenge that suited them.

We also challenged the children to inspect the tans and identify common lengths and angles. Considering the square side length to be one unit, there are various lengths of one or two units (shown in Fig. 5).

There are also three tans with a $\sqrt{2}$ length and one with a $2\sqrt{2}$ length. Although this was beyond their ability level, the children were encouraged to identify these non-integral lengths by matching edges together. To complete their familiarisation with the puzzle pieces, the children were asked to try to make copies of the other tans from the small triangles.

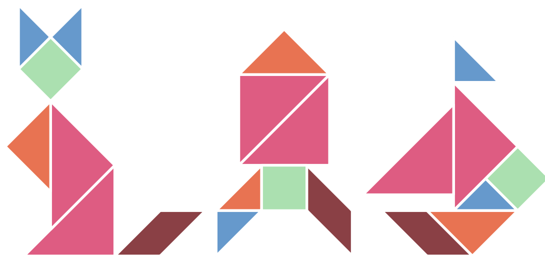


Figure 4. Tangram patterns ‘cat’, ‘rocket’ and ‘sailboat’

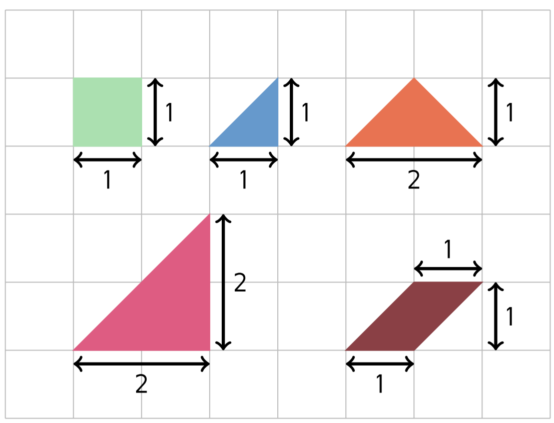


Figure 5. Common integral lengths in Tangram pieces

An interesting puzzle is to attempt to make a square from n tans, for $n = \{1, \ldots, 7\}$. The puzzle is trivial for $n = 1$, and $n = 2$ does not present much challenge. The answer for $n = 7$ is shown in Fig. 3. Of the others, one is impossible, and it is a good exercise in systematic thinking and resilience for children to identify which one.

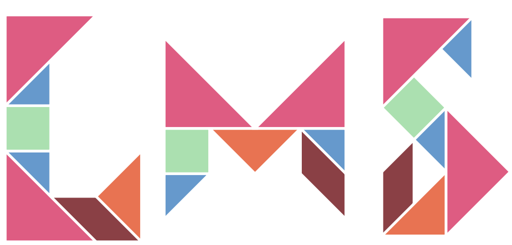


Figure 6. Letters using tangram pieces

Finally, we challenged the children to make other polygons, the numerals 0–9 and letters A–Z (some examples are shown in Fig. 6). These puzzles are usually attempted with all seven tans, but we did not enforce this rule. We provided a sheet of figures to copy and encouraged the children to make up their own.

Next steps

When buying equipment, we particularly aimed to buy versatile items that would enable the school to run further extracurricular maths activities. We imagine rerunning the club, perhaps extending it to other age groups. We are keen to explore whether pupils who were part of the original club could be encouraged to further develop their confidence in a lunchtime club where they would demonstrate games and activities to other interested children.

Acknowledgements

We are grateful to the LMS for funding, to Middleton Primary and Nursery School for operating the club and to Colin T. Graham for providing a tangram resource, which served as useful inspiration.

Peter Rowlett

Peter is an academic at Sheffield Hallam University. His teaching includes game theory and recreational mathematics, and he enjoys playing mathematical games with his nine-year-old son.

Gwilym Jones

Gwilym is a teacher at Middleton Primary and Nursery School in Nottingham. He coordinates the maths curriculum across the school and is particularly interested in fostering children’s creativity in the subject. Outside the classroom, his main passion is music; however, with two young children, this mainly consists of dancing around the kitchen to Fleetwood Mac with his family.

A Mathematician Like Me

JORDAN MARAJH, ADAM ONUS, MARIA F. PINTADO

The *A Mathematician Like Me* series at Queen Mary University of London aims to inspire future mathematicians by highlighting a range of individuals working or studying in mathematical fields. Members of our EDI team spoke with mathematicians from a range of backgrounds to learn about their journeys in mathematics.

Introduction

The history of mathematics is a complex narrative, with a large cast of characters, each building upon the work of their predecessors and engaging with the ideas of their contemporaries. However, mathematics as it is traditionally taught often reduces this vibrant history to an exercise of memorisation and the repetitive application of formulae. On the rare occasions when the history behind a topic is discussed, it is usually a brief tangent about a single genius — often a white man — who revolutionised a field of research. This narrow portrayal alienates learners who struggle to see themselves reflected in these so-called 'geniuses', which contributes to the stigma that mathematics is inaccessible or too difficult for the average person, thus perpetuating a limited and unenlightening view of what mathematics truly is and who it is for.

If you ask a typical mathematics student entering university what they envision doing with their degree, the most common responses might include teaching or expressing regret about not choosing a finance-related path. If you then ask them to name a mathematician, the most likely answers will probably include Turing, Einstein and Newton. Even setting aside that Einstein was a physicist, this limited set of names does not reflect the diversity or reality of the mathematicians we encounter in our daily lives. Why should a student feel invested in their mathematics degree if they cannot see themselves represented as mathematicians? When the fallacy persists that only revolutionary, tormented geniuses can excel at mathematics, how can the average student believe that they, too, can succeed in the field?

It is well documented that having positive representation and role models help motivate students from minority backgrounds to pursue careers in STEM (see, e.g., [2]). At Queen Mary University of London (QMUL), we are uniquely positioned within a rich and vibrant community, which highlights the importance of promoting diverse representation in mathematics. Approximately half of our students are the first in their family to attend university, and around three-quarters come from ethnic minority backgrounds. This unique context prompted us to reflect: what can we do to better support and empower our community?

QMUL 2030 Strategy

The 2030 Strategy at QMUL is to create a truly inclusive environment where students and staff celebrate their diversity and are proud to be part of the university. The strategy is built on five core values: inclusiveness, pride, ambition, collegiality and ethics.

We aim to cultivate a stronger sense of belonging among our students by exhibiting examples of diverse representation and empowering them to embrace their ambitions, excel in their studies and confidently pursue their careers.

This ongoing project on diversifying the mathematics curriculum at QMUL began in the summer of 2022, when we compiled a collection of short biographies of under-represented mathematicians that could be easily incorporated into undergraduate modules [4]. However, a recurring theme we observed was that many students are hesitant to engage with academic staff. For this reason, our goal shifted as the project continued into the summer of 2023 towards bridging this divide. This direction led to the creation of the *A Mathematician Like Me* video series [6], a collection of short video interviews featuring mathematicians from diverse backgrounds and fields. In these interviews, participants discuss what they enjoy about mathematics, the people or experiences that motivate them, and the often-overlooked challenges they face. The aim is to shed light on the interviewee's passions and relatable challenges and to showcase their multifaceted experiences beyond the traditional image of academics confined to writing equations on a chalkboard.

This series of videos is an essential component in addressing the issue of representation in mathematics. It challenges (mis-)representation at all levels, while working to dismantle preconceptions and expand the narrative of what it means to be a mathematician. Although there is still much work to be done, this project represents a meaningful step towards a more inclusive and relatable vision of mathematics.

Figure 1. Members of the EDI committee at the School of Mathematical Sciences in QMUL receiving the Faculty Award for Equality, Diversity and Inclusion 2023 from the Vice-Principal Wen Wang. Left to right: Christo, Jordan, Norberto, Wen, Silvia, Claudia, Adam, Maria and Kabiru

Our strategy

When the decision to conduct video interviews was made, the next step was to carefully craft the questions to be asked. A key factor influencing the development of these questions was the desired length of the videos. We aimed for an average duration of five to ten minutes to balance conciseness with substance and effectively achieve the goals outlined in the previous section.[1] These questions would make the core of the interview, which was structured in three main parts.

The interviews began with a brief introduction, where the interviewee shared their name, affiliation and any additional information they deemed relevant, such as their research interests or a summary of their career trajectory. This was followed by four core questions, asked sequentially. In some cases, an additional question about inclusivity at QMUL was incorporated, where applicable. Finally, the interviewee was invited to share any concluding remarks, if they wished to add something beyond the predefined structure.

The questions posed to the interviewees were as follows:

(1) What is one exciting thing about being a mathematician?

(2) Did you have a role model who motivated you to become a mathematician or someone you look up to? How has this influenced your path?

(3) What obstacles have you encountered along your journey in science that you believe are specific to a lack of diversity, and how did you overcome them?

(4) Reflecting on the challenges in your career, is there any advice for aspiring or early career mathematicians who are facing the same obstacles?

These questions were designed to set a thoughtful and engaging tone for the interviews and to provide a natural transition into deeper and more sensitive topics. The first question serves as an icebreaker, encouraging interviewees to share a personal or professional perspective on their field while offering insights into their personality, experiences and current roles. The second question explores the importance of role models, aiming to highlight how influential figures can shape and inspire mathematical careers. The third question addresses more sensitive topics, touching into challenges rooted in under-representation and lack of diversity. While this question could evoke vulnerability, it also shines light on the resilience and strength of the interviewee, who can offer relatable experiences that can inspire the viewers. Lastly, the final question builds on the discussion of challenges by inviting interviewees to provide advice for those under similar circumstances, whether it be related to a lack of diversity in mathematics or to mathematics as a discipline in general, making it relevant to aspiring mathematicians and a wider audience.

The individuals featured in the video series were primarily members of QMUL, since the project's main target audience are the university's students.

However, we also included external mathematicians with ties to the team to enrich the diversity of perspectives, for example, Federico Ardilla, Tyler Kelly and Bethany Marsh.

[1] In practice, the shortest video is approximately three minutes long, while the longest spans 17 minutes.

Our selection process prioritised individuals from a variety of backgrounds and circumstances, enabling the project to capture a wide range of experiences that would resonate with viewers. Interviews were conducted either in person or online, depending on the interviewee's availability, and were facilitated by the team member who had a direct connection to the participant.

This project was a true cooperative effort between team members. From setting clear objectives and selecting candidates to refining interview questions and video editing, every stage was the result of collaborative effort. The exchange of ideas, collective decision-making and shared dedication were instrumental in bringing this initiative to life and ensuring its success.

Resources, impact and outreach

An important message that we wanted to convey clearly is that *anyone can be a mathematician*. To this end, videos were chosen as a primary resource of communication. Living examples of mathematicians are imperative to the goal, but the sharing of initiatives such as the present project with the community is equally important.

EDI projects in QMUL

This project is not the only one of its kind at QMUL. The idea of co-creation has permeated all the EDI projects undertaken in the School of Mathematical Sciences (SMS) and beyond, including efforts to highlight the historical contributions of different cultures to mathematics [1].

Other schools within the Faculty of Science and Engineering have adapted the initiatives of the SMS by extending the resources to their own fields [3].

We were invited to visit Preston Manor School in Wembley on 8 November 2023 to present the work on 'Diversifying the Maths Curriculum' [4] to both students and teachers (Fig. 2). We also shared our contributions with Ruislip High School and other members of the Vanguard Learning Trust.

Moreover, the video project and booklet gained the attention of Big Ideas, which is currently collaborating with members of our EDI group and a local school in Islington on a peer research project surrounding the idea — who can be a mathematician? In addition to the resources mentioned, a series of posters featuring mathematicians in the booklet were created and have received positive feedback [5].

These projects have been presented by members of the EDI committee at various conferences and events such as the Piscopia Initiative's *PiFORUM23 & 24*, the *Queen Mary Festival of Education*, the *British Applied Mathematics Colloquium 2024* and *Maths Taster Days at QMUL*, among other internal and external EDI events.

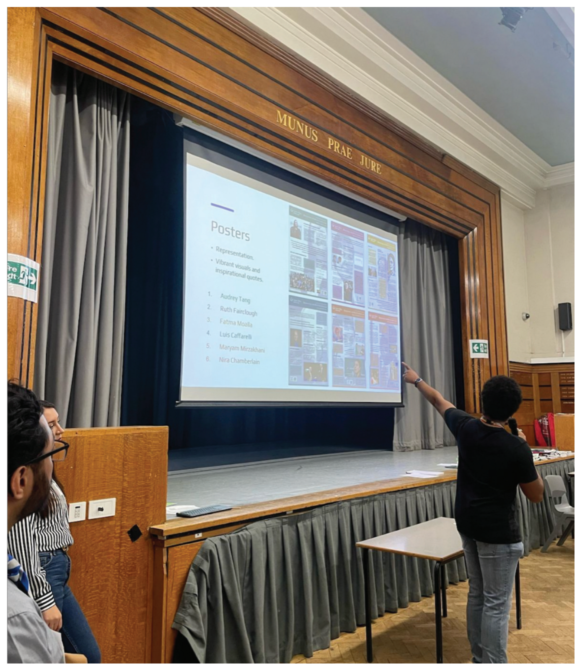


Figure 2. Visit to Preston Manor School to present the work on 'Diversifying the Maths Curriculum' in November 2023

In any setting surrounding mathematics, the materials resulting from the collaborative efforts of the EDI team at the school permit a more holistic view of the subject while shedding light on hidden figures in the maths community. Our resources have the potential to influence not just schoolchildren to pursue a degree in maths but also current mathematicians to be motivated in their careers. It is by sharing projects of this genre that we hope to inspire individuals from a variety of backgrounds to pursue mathematics to their heart's content.

Acknowledgements

We would like to thank the other members of the EDI team whose contributions have been invaluable to this project. In particular, we would like to thank Professor Claudia Garetto for her guidance in coordinating this initiative and for the support provided to the PhD students involved in the project.

We are deeply grateful to the individuals featured in the video series. Their stories inspire us and motivate us to continue our efforts towards greater inclusivity and representation in mathematics.

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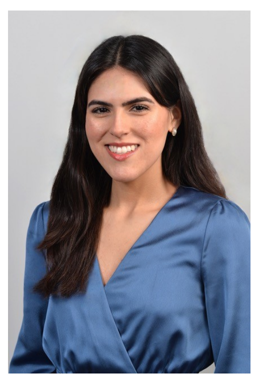
Jordan Marajh

Jordan is a third-year PhD student in the SMS at QMUL. His research interests are in mathematical relativity, specifically in conformal methods, differential geometry and the analysis of hyperbolic PDEs. He is rarely found without a set of rings on, but occasionally takes them off when the going gets tough when playing the classic rhythm game Osu!.

Adam Onus

Adam is a fourth-year PhD student in the SMS at QMUL. Their research interests are in applied algebraic topology and topological data analysis, with a particular interest on applications of cellular sheaves. They can usually be found at conferences knitting or crocheting Klein bottles or other fun topological surfaces!



Maria F. Pintado

Maria is a fourth-year PhD student in the SMS at QMUL. Her research interests are in Bayesian statistics. When she is busy running simulations, she can often be found playing sudoku.

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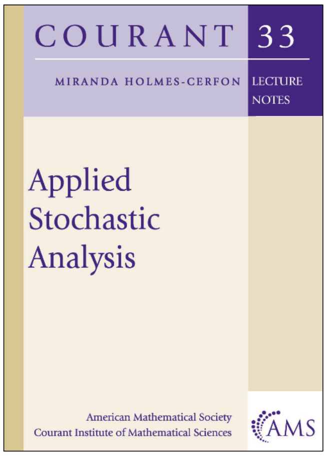

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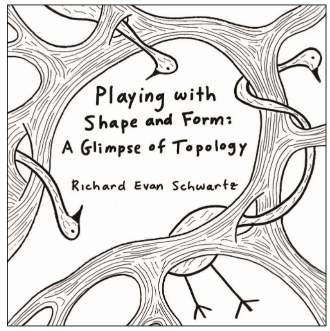

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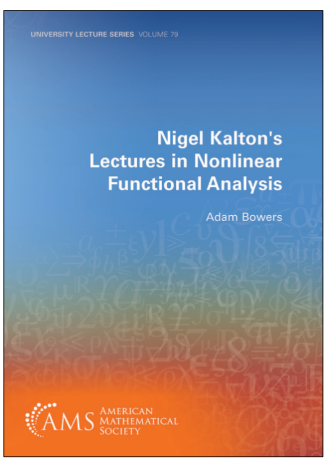

NIGEL KALTON'S LECTURES IN NONLINEAR FUNCTIONAL ANALYSIS

Adam Bowers, University of California

University Lecture Series, Vol. 79

The main theme of this book is the nonlinear geometry of Banach spaces, and it considers various significant problems in the field. The present book is a commented transcript of the notes of the graduate-level topics course in nonlinear functional analysis given by the late Nigel Kalton in 2008. Collected here are the topics that Nigel Kalton felt were significant for those first dipping a toe into the subject of nonlinear functional analysis and presents these topics in an accessible and concise manner.

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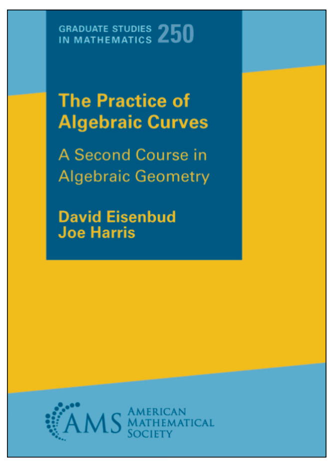

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Notes of a Numerical Analyst

Prime Gaps and Numerical Eigenvalues

NICK TREFETHEN FRS

Despite their similar names, number theory and numerical analysis are about as far apart as you can get in mathematics. To oversimplify outrageously, all that number theorists care about is integers, and all that numerical analysts care about is real numbers. It's chalk and cheese, discrete and continuous, algebra and analysis.

So my interest was just that of an onlooker when I heard a few years ago about big results concerning prime gaps. First, Yitang Zhang proved that there are infinitely many pairs of primes separated by less than $70{,}000{,}000$. Then James Maynard showed that $70{,}000{,}000$ could be improved to 600 [1]. (Nine years later he was awarded a Fields Medal.) The current best result is that there are infinitely many primes separated by gaps no greater than 246 [2].

3,5	**5,7**	**11,13**	**17,19**
29,31	**41,43**	**59,61**	**71,73**

Figure 1. It is not known if there are infinitely many pairs of primes like these that differ by just 2, but it has been proved that there are infinitely many that differ by no more than 246

But who knew that all these theorems depend on calculating eigenvalues of matrices? I learned this during a lunch with Maynard (whom I thank for contributing to this column). "This number 246", I asked him, "it must come from some kind of calculation, right? What is the calculation?"

Maynard surprised me by explaining that it's the numerical calculation of an eigenvalue of a matrix. It turns out that if you can prove that a certain $1{,}780 \times 1{,}780$ matrix has an eigenvalue >4, you have proved that there are infinitely many prime gaps ≤ 246. The number 246 is the smallest gap size for which the relevant matrix has this property.

The number theory details can be found in the papers just cited. I'd like to say a word about this other aspect, the method of proving something rigorously by a real number computation, even though real numbers can only be approximated on our computers.

A famous tool is *interval arithmetic*, and you might imagine this is what Maynard and his collaborators must have used. In interval arithmetic, when two numbers are combined by (say) division, although the exact result is not be stored, upper and lower bounds are retained. As a calculation proceeds, the gap between the upper and lower bounds widens, but the bounds are rigorous.

The trouble is that this can be terribly pessimistic in practice. So for years I had a low opinion of interval arithmetic, until I learned that many results in this area are attained in a cleverer, a posteriori fashion. You compute your result by ordinary numerical means, and then you *validate it* [3]!

Suppose, say, you've computed a numerical eigenvector x and eigenvalue λ of a symmetric matrix A. The computations are not rigorous. But now, you validate your result by rigorously computing a bound $\|Ax - \lambda x\|_2 \leq \varepsilon$ on the residual by interval arithmetic or other means. This implies that A has an eigenvalue within a distance ε of λ. Maynard and his collaborators used a one-sided bound, not intervals, but the a posteriori nature of their rigorous calculation was exactly this.

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Nick Trefethen

Trefethen is Professor of Applied Mathematics in Residence at Harvard University.

Mathematics News Flash

Jonathan Fraser reports on some recent breakthroughs in mathematics.

Kakeya sets in three dimensions

AUTHORS: Hong Wang, Joshua Zahl
ACCESS: arxiv.org/abs/2502.17655

A Kakeya set in $\mathbb{R}^d$ is a set that contains a unit line segment in all possible directions. For example, the unit ball is a Kakeya set. However, counter-intuitively, there exist Kakeya sets (for all $d \geq 2$) that have zero d-dimensional volume (zero area in the plane). These examples were first constructed by Besicovitch more than 100 years ago. Despite the existence of these curiously small Kakeya sets, the Kakeya conjecture asserts that Kakeya sets should still be large in terms of dimension. That is, a Kakeya set in $\mathbb{R}^d$ must have Hausdorff dimension d. This was settled by Roy Davies in 1971 for $d = 2$, but the higher-dimensional cases have turned out to be extremely difficult, attracting the attention of some of the best in the business, including Jean Bourgain, Tom Wolff and Terry Tao.

Part of the fame of the Kakeya conjecture is that it is related to a whole hierarchy of problems in harmonic analysis. Notable examples include the restriction problem (which investigates the problem of restricting the Fourier transform to the surface of a sphere), the Bochner–Riesz conjecture (which concerns the convergence of certain Fourier series) and the local smoothing conjecture (which deals with solutions to the wave equation). In fact, these conjectures are all open and each one is implied by the next conjecture in the list (local smoothing $\Rightarrow$ Bochner–Riesz $\Rightarrow$ restriction $\Rightarrow$ Kakeya). As such, if you really want to upset a room full of harmonic analysts, then you should find a counterexample to the Kakeya conjecture!

This paper constitutes a major breakthrough in analysis. It appeared on arXiv in February 2025. It is 127 pages long and resolves the Kakeya conjecture for $d = 3$. The authors, Wang and Zahl, have been making tremendous inroads on Kakeya and related problems in recent years, but this is surely their greatest work to date.

Optimality of Gerver's sofa

AUTHOR: Jineon Baek
ACCESS: arxiv.org/abs/2411.19826

Suppose you have just purchased a new sofa. You are now faced with the problem of moving it from the front door of your house to your living room, which might involve going round a corner. Will the sofa fit?

The following is a more precise formulation of this problem, due to Moser (1966). Suppose your sofa is a convex subset of the plane and you want to move it around a right-angled corner in a corridor that is 1 unit wide. What is the largest possible area of a sofa that can be moved successfully around the corner? To begin with, our readers may enjoy trying to find by themselves sofas that work (spoiler warning ahead). A simple first example could be a 1×1 square (a futon, perhaps?) that you can push all the way into the corner and then change direction and pull it down the other way. Can you beat area 1? I can: a half-circle of diameter 2 will work (and this has area $\pi/2 \approx 1.57$). Can you see how? It turns out that one can do much better than this. In 1992, Gerver proposed a design (which actually looks like quite a reasonable design for a sofa) that is the area bounded by 18 carefully chosen curves. It works and has area ~ 2.2195. Various attempts at an upper bound have been made over the years, including a computer-assisted proof by Kallus and Romik (2018), which proved that anything with area larger than 2.37 would not work.

This paper, a remarkable 119-page opus that appeared on the arXiv in November 2024, finally settles this problem: Gerver's sofa is optimal!

Jonathan Fraser is a pure mathematician based in St Andrews. He works in analysis, fractal geometry and dynamical systems. He is pictured here alongside a young collaborator, both deep in thought.

Microtheses and Nanotheses provide space in the Newsletter for current and recent research students to communicate their research findings with the community. We welcome submissions for this section from current and recent research students. See newsletter.lms.ac.uk for preparation and submission guidance.

Microthesis: Discrete Moments of the Riemann Zeta Function

ANDREW PEARCE-CRUMP

Let $\zeta(s)$ denote the Riemann zeta function. Shanks conjectured that $\zeta'(s)$, when evaluated and summed over the non-trivial zeros of the zeta function, is real and positive on average. This is strange. A complex-valued function summed over unrelated complex points is real on average. What happens for powers of $\zeta'(s)$?

The Riemann zeta function

The Riemann zeta function is defined as

$$\zeta(s) = \sum_{n=1}^{\infty} \frac{1}{n^s} = \prod_p \left(1 - \frac{1}{p^s}\right)^{-1},$$

which converges for all complex numbers s with $\Re(s) > 1$, where $\prod_p$ denotes a product over all prime numbers p. The zeta function can be extended meromorphically to the whole complex plane, with a simple pole at $s = 1$.

This second formulation of the zeta function, known as the Euler product, shows just why we are interested in it: understanding this function should improve our understanding of the prime numbers.

The prime number theorem

Let $\pi(x)$ denote the number of prime numbers less than or equal to some real number x. The prime number theorem states that

$$\pi(x) \sim \frac{x}{\log x}$$

as $x \to \infty$.

In his 1859 memoir, Riemann sketched how to relate this problem about primes to the zeros of the Riemann zeta function. The proof was later completed by Hadamard and de la Vallée Poussin in 1896, and it solidified the importance of understanding the zeta function in its entirety.

Zeros of the Riemann zeta function

The non-trivial zeros of zeta, denoted $\rho = \beta + i\gamma$, lie in the region $0 < \Re(s) < 1$. Due to the symmetry of the zeros in this region, Riemann conjectured that they all have real part $1/2$ (which we assume here). This is literally the million-dollar problem, one of the seven Millennium Prize Problems set by the Clay Mathematics Institute.

An equivalent form of the Riemann hypothesis is that the derivative of $\zeta(s)$ has no zeros in the region $0 < \Re(s) < 1/2$. This gives us a clear indication of why studying the derivative is of interest.

Clearly, the Riemann hypothesis is a very hard problem, going back over 165 years! A more tractable problem is to study the zeta function on average, which is known as calculating its moments. Understanding different types of moments has driven progress in proving the Riemann hypothesis, the simplicity of the non-trivial zeros and many other related problems.

Moments

In this microthesis, we consider discrete moments, which are used in the study of the simplicity of the non-trivial zeros. For k an integer, they take the form

$$\sum_{0<\gamma\le T} \zeta'\left(\frac{1}{2} + i\gamma\right)^k$$

as $T \to \infty$, where the sum is over the non-trivial zeros of $\zeta(s)$, given by $1/2 + i\gamma$.

Shanks's conjecture [5], which states that $\zeta'(1/2+i\gamma)$ is real and positive on average, is the case $k = 1$, which was proved by Conrey, Ghosh and Gonek [1] as a side calculation when they showed that there are infinitely many simple zeros of the zeta function.

Calculating higher moments analytically is typically difficult. Instead, we predict the answers using random matrix theory (RMT), where a random matrix is what it sounds like: a matrix with random entries.

A chance meeting in Princeton

The Riemann hypothesis is about the horizontal distribution of the zeros of the zeta function. However, Montgomery was investigating the vertical distribution through a result known as pair correlation.

In April 1972, Montgomery was introduced to Dyson during his visit to the IAS in Princeton. When Montgomery told Dyson about his results, Dyson realised that they were the same as those in his work in RMT. They had discovered a previously unnoticed link between two seemingly disparate areas, and it was ready to be exploited.

Moments and RMT

It appears that the statistical properties of the zeros of the zeta function are the same as those of eigenvalues of random unitary matrices. This relationship was first exploited to predict moments in number theory by Keating and Snaith [3].

They predicted the behaviour of the moments of the zeta function on the critical line, based on calculations on the RMT side. Specifically, they conjectured that for k a non-negative integer,

$$\int_0^T \left|\zeta\left(\frac{1}{2}+it\right)\right|^{2k} dt \sim a_k \prod_{j=0}^{k-1} \frac{j!}{(k+j)!} T(\log T)^{k^2}$$

as $T \to \infty$, where a_k is a known product over primes.

Note that Keating and Snaith had to insert the product over primes after their RMT calculation to form their number theory conjecture. Later, a hybrid model approach [2], one that weights zeros and primes equally, was used to recreate their conjecture.

RMT has since become an indispensable tool for predicting solutions of unsolved problems in number theory.

Following a similar approach to that used by Keating and Snaith, we predict that for k a non-negative integer,

$$\sum_{0<\gamma\leq T} \zeta'\left(\frac{1}{2}+i\gamma\right)^k \sim \frac{1}{(k+1)!}\frac{T}{2\pi}(\log T)^{k+1}$$

as $T \to \infty$. This prediction is also valid when $k = -1$, if we also assume the simplicity of the non-trivial zeros of $\zeta(s)$.

Note that there is no arithmetic component in this conjecture. That is, there is no product over primes. This prediction comes from considering this problem through the hybrid model approach.

The strange behaviour that Shanks first noticed is predicted to continue for larger integer values of k. What causes this behaviour? See [4] for the answer!

Acknowledgements

The author is currently supported by the Heilbronn Institute for Mathematical Research. His PhD thesis is supported by the University of York.

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Andrew Pearce-Crump

Andrew is a Research Fellow at the University of Bristol. His primary research interests are number theory and RMT, particularly at their intersection. He enjoys playing the Dutch sport korfball and watching rugby.

Obituaries of Members

Frederick Richard Allen: 1930–2024

Frederick Richard Allen, who was elected a Member of the London Mathematical Society on 28 February 2013, died on 14 June 2024, aged 93.

Louise Dop writes: Dr Frederick Richard Allen was born in Godalming, Surrey, on 21 December 1930. Awarded a scholarship in 1942, he attended Newbury Grammar School. Excelling in mathematics and on the cricket pitch, he revisited fond memories of this period throughout his lifetime.

In 1949, Frederick won a County Major Scholarship to attend the University of Reading, where he earned First Class Honours in Mathematics and Physics and then in Mathematics (Special Honours). He continued his studies at Reading under Professor Neville and completed a PhD in mathematics in 1955 with his thesis *Metrical Differential Geometry of One-Parameter Families of Surfaces in Euclidean Space of Three Dimensions*.

After briefly working at the Patent Office at the Ministry of Supply, in 1956, Frederick answered the call to join the Royal Navy on a three-year short service commission. After training, he reported to the School of Navigation and Direction at HMS Dryad, Portsmouth, where he worked on the development of new navigational aids and as a radar instructor. He met his future wife Mhairi around this time. They later married in 1959.

Returning to the Civil Service, Frederick was seconded to Harwell to work on the design of nuclear-powered ships. At Harwell, scientists and engineers were encouraged to do their own programming to solve problems and, supported by a specialist Computer Group, Frederick honed his skills in programming techniques and numerical analysis for solving complex problems in mathematical physics.

In 1959, Fredrick moved to Winfrith Heath, Dorset, to work on the development of commercial nuclear reactors for the UKAEA. He moved with his wife and young twin sons to a new house in Broadstone near Poole. With the addition of a daughter, it became his home until his death.

It was an exciting time at Winfrith. The team worked on a pioneering design for the steam-generating heavy water reactor (SGHW). Frederick's development of theoretical methods proved instrumental for interpreting experimental results and the design of the 100 MW(e) Prototype SGHWR built at Winfrith.

By the 1980s, the advent of large computer models that simulated the flow of fluids in oil reservoirs led to a new specialisation that aligned well with the experience of the mathematical physicists at Winfrith. Aiming to enhance oil recovery, Frederick headed a team working to simulate the North Sea oilfields. This interesting development led to travel opportunities in the USA and Canada, including a visit to a working oil rig.

Frederick retired from the UKAEA in 1990 but continued as an independent consultant in the development and application of theoretical methods and software development.

Frederick enjoyed a fulfilling retirement with Mhairi until her death in 2019. He pursued his passion for mathematics with independent research around the Riemann hypothesis and amused his grandchildren by programming chess games and sudoku solvers. He played the violin with passion and became a prolific 'correspondent via email'. His fierce intellect and near perfect recall remained until his death.

Chris Houghton: 1938–2024

Dr Chris Houghton, who was elected a Member of the London Mathematical Society on 20 January 1972, died on 6 May 2024, aged 85.

Martin Dunwoody writes: Chris Houghton was born in Croydon on 4 December 1938. He was a student at Whitgift School and went on to study at UCL. After graduating, he went to UMIST in Manchester to study for a PhD in group theory with Hannah Neumann and Jim Wiegold. In 1963, he went to Uganda as a lecturer in mathematics at Makerere University College. He returned to England in December 1966, where he had a post at Coventry Polytechnic for a short period before taking up a permanent position at Cardiff University College, where he stayed until his retirement in 2004.

In a paper that appeared in 1974, Chris defined $e(G, H)$, the number of ends of the pair of groups $G > H$, which initiated research on relative versions of Stallings' theorem. In a short paper in 1978, Chris introduced what came to be known as the Houghton groups, which have become an item in the toolkit of geometric group theorists. The Houghton group H_n is the group of permutations of the points on n rays of discrete points starting at a common base point, which eventually restrict to a translation on each ray.

In September 1967, Chris married Judy, whom he had met at Manchester, and they had three daughters. Chris and Judy moved to Cambridge in 2006 to be close to one of their daughters. They had a love of walking and took many walking holidays in the UK together with fortnightly walks with the U3A. During the year I spent at Makerere, Chris led a memorable trek of a group of about ten students and myself up a 12,000-foot extinct volcano on the border with Rwanda. It started raining heavily as we got to the summit.

Chris is survived by Judy, their three daughters and four grandchildren.

Peter E. Newstead: 1941–2024

Photo credit: Gert-Martin Greuel. Source: Archives of the Mathematisches Forschungsinstitut Oberwolfach.

Peter Edward Newstead, elected a member of the LMS on 19 October 1972, died on 27 July 2024 aged 82.

Nigel Hitchin writes: In the early years, Peter was a mainstay of the small community of algebraic geometers in the UK, but his foundational work in the 1960s on moduli spaces became highly relevant 20 years later when ideas from theoretical physics entered the area. At that point, when interest in the subject had broadened considerably, he inaugurated a research group VBAC (Vector Bundles on Algebraic Curves), which brought together mathematicians from around the world with regular workshops and meetings.

Peter was born in Dunoon, Scotland, where his father was stationed as a submarine commander. After the war, the family moved to Surrey, where he attended a prep school and then won scholarships, first to Winchester and then in 1958 to Trinity College, Cambridge. There he was supervised first by J.A. Todd and then by M.F. Atiyah.

Atiyah's own thesis some years earlier had started the serious study of higher rank holomorphic vector bundles on curves, but by this time, the notion of stability due to D. Mumford had come into play and Peter's early papers put this to great effect in calculating the cohomology of some of these moduli spaces and identifying them with known algebraic varieties.

After spending the year 1964/65 in Oxford following Atiyah's move there, Peter was appointed an Assistant Lecturer in Liverpool in 1965. Liverpool was his home for the rest of his life. He met his wife Ann there, and he was a "shrewd and well-informed member of departmental committees and … a leading light in the Liverpool Mathematical Society", as a colleague recalls. Liverpool provided few research students, however, but this was where Peter's international contacts, and VBAC in particular, enabled him not only to host numerous visitors but also to mentor many young geometers from around the world. He would "listen patiently, smile, and then after a thoughtful silence, confirm or refute the suggestion", as one remarked. The research group also brought more collaborators, especially on the subject of Brill–Noether loci, the analogue of special divisors for higher rank bundles, which became a favourite theme.

Peter and Ann would invariably travel together to the workshops and meetings, once to Mexico for his 65th birthday conference without taking any flights! His legacy lies not only within his mathematics works but also the VBAC community.

David Tall: 1941–2024

Photo credit: Susan Tall

Professor Emeritus David Tall, who was elected an LMS member on 21 December 1967, died on 15 July, aged 83.

Ian Stewart writes: David Orme Tall was educated at Wellingborough Grammar School and Oxford University, where he obtained a DPhil under Michael Atiyah. In 1966, he became a lecturer at Sussex University, moving to Warwick University's Mathematics Department in 1969 with the specific task of improving its focus on teaching. Later, he moved to

Warwick's Mathematics Education Department. After retirement, he became Emeritus Professor in Mathematical Thinking.

David was especially interested in education at undergraduate level, as the mathematical concepts are challenging and the thought processes are abstract. Students who are very capable at school level often struggle, discovering that a mastery of algorithmic techniques does not prepare them for the more conceptual nature of university mathematics. David felt that these struggles could be avoided if both student and teacher were aware of the reasons behind them. This led him to investigate the workings of mathematical minds, seeking broad general principles.

He became a world authority on undergraduate mathematics education, especially on how mathematicians become accustomed to new concepts (as a student learning them) or invent them (in research). With Eddie Gray, he formulated the highly influential notion of a 'procept': a process, which later becomes a mathematical object, and is then reduced to symbolic form. More recently he identified three fundamentally different — but interrelated — ways of thinking about mathematics: embodied (in visual and other senses), symbolic and formal. This triad is known as 'Tall's three worlds of mathematics'.

David took a keen interest in nonstandard analysis, developing his own concrete approach in which mathematical telescopes and microscopes reveal infinities and infinitesimals geometrically. He wrote software to make this approach accessible and intuitive.

Mathematics education aside, David had two other great passions: his family and music. He was devoted to all three generations of his family, as they were to him. He was involved in many musical activities. He was especially fond of the music of Delius, Gershwin and Percy Grainger, and in 1977, he formed the Percy Grainger Society, becoming its chairman. In 1991, he was awarded the Bronze Medallion of the International Percy Grainger Society.

Despite growing health problems, David continued his research long after retirement. We met occasionally at his home in Kenilworth, discussing the revision of *Complex Analysis* and chatting about mathematical thought processes, usually with a CD playing in the background. He was an inspiring educator, a wonderful family man and a lifelong friend.

David is survived by his wife of 61 years, Sue, his three children Rebecca, Christopher and Nicholas, and six grandchildren.

Death Notices

We regret to announce the following deaths:

- Professor Emeritus David Larman, formerly of University College London, who was elected an LMS member on 16 December 1964, died on 18 March, aged 84.

18th Colloquia in Combinatorics 2025

Location: QMUL and UCL
Date: 7–8 May 2025
Website: 2dcic.github.io

Talks will cover a wide range of topics of interest to all working in combinatorics or related areas.

The speakers will be Giulia Codenotti (FU Berlin), Maria-Romina Ivan (Cambridge), Allan Lo (Birmingham), Sam Mattheus (Brussels), Jozef Skokan (LSE), Laura Vargas Koch (Aachen), Natalie Behague (Warwick), Bill Jackson (QMUL), Gil Kalai (Reichman), Richard Montgomery (Warwick), Fiona Skerman (Uppsala) and Raphael Steiner (ETH Zürich).

These colloquia are supported by an LMS Conference Grant and an HIMR Small Grant.

Geometric Problems in Linear and Nonlinear PDEs

Location: Sabhal Mor Ostaig, the Isle of Skye
Date: 16–20 June 2025
Website: tinyurl.com/5b6jafpt

Geometric analysis has intrigued mathematicians for centuries and remains a vibrant area of modern mathematics. Central to this field are the formulation of both linear and nonlinear partial differential equations (PDEs) on manifolds and the minimisation of energy functionals in infinite-dimensional spaces. Our workshop will focus on four closely interconnected areas within geometric analysis: characterising solutions to PDEs, Euler equations, minimal surface theory and spectral geometry. The event aims to bring together leading experts and early career researchers from around the world to discuss the latest advances, exchange ideas and explore major challenges and open problems in the field.

We acknowledge the support of the London Mathematical Society, ICMS and Glasgow Mathematical Journal Trust. The event is organised in partnership with the Clay Mathematics Institute.

This event is supported by an LMS Conference grant.

LMS Meeting

South West and South Wales Regional Meeting 2025

14–16 May 2025, Cardiff

Website: tinyurl.com/2rx8924b

Opening of the Meeting & Society Business

The speakers will be André Henriques (Oxford) and Ehud Meir (Aberdeen). The full programme is to be confirmed. These lectures are aimed at a general mathematical audience. All those interested, whether LMS members or not, are most welcome to attend this event.

Registration and Society Dinner

For further details about the South West and South Wales Regional Meeting 2025 and for how to register for a place, please visit lms.ac.uk/events/lms-south-west-and-south-wales-regional-meeting-2025.

Travel Support for Members and Research Students

Funds are available for partial support to attend the meeting and workshop. Requests for support with an estimate of expenses should be addressed to the organisers.

Midlands Regional Meeting & Workshop

Location: Lincoln
Date: 17–20 June 2025
Website: tinyurl.com/ym59bvpd

LMS Regional Meeting Speakers (17 June 2025)

The first day features lectures by Francesco Fournier-Facio (University of Cambridge), Oihana Garaialde Ocaña (University of the Basque Country) and Simon Smith (University of Lincoln). Talks take place in the Main Lecture Hall, INB0114, of the Isaac Newton Building.

These lectures are aimed at a general mathematical audience. All those interested, whether LMS members or not, are most welcome to attend this event.

Workshop Speakers (18–20 June 2025)

The follow-up workshop features research mini-courses by Oihana Garaialde Ocaña (University of the Basque Country), Simon Smith (University of Lincoln) and Stephan Tornier (University of Newcastle, Australia), along with research talks by early career mathematicians Rudradip Biswas (Warwick), Stacey Law (Birmingham) and Anja Meyer (Loughborough).

Talks and breaks during the Research Workshop will take place in rooms LMS0005 (Medical School Building, right across the Pond) and INB1103 (Isaac Newton Building).

The meeting forms part of the Midlands Workshop *Groups in the Midlands* in Lincoln on 18–20 June 2025.

Registration

For further details about the Midlands Regional Meeting and to register for a place, please visit lms.ac.uk/events/lms-midlands-regional-meeting-2025.

Travel Support for Members and Research Students

Funds are available for partial support to attend the meeting and workshop. Requests for support, including an estimate of expenses, as well as all queries about the two events may be addressed to one of the organisers: Yuri Santos Rego (YSantosRego@lincoln.ac.uk) and Paula M. Lins de Araujo (PMacedoLinsDeAraujo@lincoln.ac.uk).

LMS Hardy Lectureship Tour 2025

Date: June to July 2025
Website: tinyurl.com/yeknvst6

Dates for the 2025 LMS Hardy Lectureship tour by Professor Emily Riehl (Johns Hopkins University) have been confirmed.

The LMS Hardy Lectureship is named after G.H. Hardy, former President of the Society and De Morgan Medallist. Originally awarded to a distinguished overseas mathematician in odd-numbered years, the LMS Hardy Lecturer visits the UK and gives the Hardy Lecture at a Society meeting, normally held in London, as well as several other lectures on different topics at other venues in the UK.

Professor Riehl was announced as the 2025 Hardy Lecturer in August 2024. Emily has established herself as a leading expert in higher category theory and has also developed an interest in connections with computer science such as homotopy type theory.

She is an accomplished and enthusiastic expositor of mathematics at a variety of levels aimed at mathematicians as well through popular writing with articles published in *Scientific American* and *New Scientist*. She also plays a leading role in the broader engagement of mathematicians and other scientists from marginalised and discriminated-against groups.

The full list of dates for the Hardy Lectureship Tour 2025 by Emily are as follows:

Friday, 20 June	Aberdeen
Monday, 23 June	Manchester
Tuesday, 24 June	Glasgow
Wednesday, 25 June	Edinburgh
Friday, 27 June	Cardiff
Monday, 30 June	Cambridge
Wednesday, 2 July	Birmingham
Friday, 4 July	London – Hardy Lecture

For further details about the tour, please visit the following link: lms.ac.uk/events/lectures/hardy-lectureship.

Summer School: Aspects of Spectral Theory for Linear Operators

Location: Universidad de los Andes, Colombia
Date: 3–6 June 2025
Website: tinyurl.com/39zh2ybr

The aim of the school will be to expose participants, mainly from Colombia and neighbouring countries, to cutting-edge research in topics associated with time-evolution problems and spectral theory. On this occasion the mini-courses will focus on

- Revivals and fractalisation (Lyonell Boulton, Heriot-Watt University, UK)
- Geometrical aspects of spectral theory (David Krejčiřik, Czech Technical University in Prague, Czech Republic)

There are currently approximately 100 registered participants, including undergraduate and graduate students and specialists with an interest in the topics to be presented. Attendees are expected to have a basic knowledge of functional analysis.

The activities will consist of a series of morning lectures given by the main speakers. The participants will have an opportunity to give a short talk or present a poster in a series of afternoon sessions. The morning lectures will be delivered in English, whereas the afternoon lectures will be held in English or Spanish.

This event is supported by an LMS Scheme 5 grant.

P@W Summer School: Recent Trends in Probability and Statistics

Location: University of Warwick
Date: 7–11 July 2025
Website: tinyurl.com/msh3azvy

The school aims at engaging PhD students and researchers with cutting-edge topics at the frontiers of current knowledge in probability and statistics. It will feature four lecture courses held by Martin Hairer (EPFL, Switzerland, and Imperial, UK), Nina Holden (NYU Courant, US), Hubert Lacoin (IMPA, Brazil) and Richard Nickl (Cambridge, UK).

The courses will explore different but connected themes: stochastic PDEs, random planar maps, directed polymers and Bayesian inference for time evolution PDEs. The programme will be complemented by discussion and exercise sessions and selected short talks by participants.

To join the summer school, please register at tinyurl.com/436vcdrh.

This event is supported by an LMS grant.

Registration deadline: 18 May 2025

LMS Meeting

LMS General Meeting and Hardy Lecture 2025

Friday, 4 July 2025, Hardy Room, De Morgan House, London, and online via Zoom

Website: tinyurl.com/us6xjdcj

This meeting will open with Society Business, during which LMS members will have the opportunity to sign the Members' Book, which will be followed by the Election of the LMS Honorary Members and the announcement of the LMS prize-winners for 2025.

A supporting lecture will be given by Clark Barwick (University of Edinburgh) followed by the Hardy Lecture 2025, which will be given by Emily Riehl (Johns Hopkins University).

A reception will be held after the meeting, which will also be held at De Morgan House. A Society Dinner will follow, with details to be confirmed.

Grants of up to £200 are available to parents and carers who wish to attend this event and require help towards caring costs. Please see the Caring Supplementary Grants page on the LMS website. Please submit your application no later than 3pm on Friday, 27 June. For any questions on Caring Grants, please contact womenanddiversity@lms.ac.uk.

See the website for further details and to register. These lectures are aimed at a general mathematical audience. All those interested, whether LMS members or not, are welcome to attend.

Continuum Mechanics in Biology

Location: University of Birmingham
Date: 1–3 July 2025
Website: tinyurl.com/yuw2hc63

This workshop addresses the interface between continuum mechanics and the life sciences. Contributions of 20-minute talks and posters are welcome. Early career researchers including PhD students are strongly encouraged to attend. Financial support is available for UK-based research students and participants with caring responsibilities. All details can be found on the website.

Register by 8 June 2025, or 18 May 2025 if contributing a talk or poster.

This workshop is funded by LMS Scheme 1.

IGST2025 Workshop

Location: University of Southampton
Date: 14–18 July 2025
Website: amplitudes.soton.ac.uk/sotonfishnets

This workshop is on fishnet quantum field theories, which are families of special models that have attracted great recent interest due to their properties interconnecting various topics in mathematical physics in a simple yet rich way. These include, among others, integrability, motivic periods and Calabi–Yau varieties.

This event will be interdisciplinary and will include review lectures to support the communication between researchers from different fields.

This workshop is funded by the LMS.

International Mathematics Competition for University Students

28 July to 3 August 2025, American University in Bulgaria, Blagoevgrad

Website: www.imc-math.org.uk

The 32nd IMC will be held in Blagoevgrad, Bulgaria. It is organised by University College London and hosted by the American University in Bulgaria, which is in Blagoevgrad.

Universities are invited to send several students and one teacher as a team leader. Individual students not in a team and without a team leader are also welcome. The competition is for students just completing their first, second, third or fourth years of university education and will consist of two sessions of five hours each. Problems will be on algebra, analysis (real and complex), geometry and combinatorics. The maximum age of participants on the last day of the IMC is normally 23 years, although exceptions can be made. The working language will be English.

The IMC in Blagoevgrad is a residential competition, and all student participants are required to stay in the accommodation provided by the hosts. The event aims to provide a friendly, comfortable and secure environment, where university mathematics students can enjoy mathematics with their peers from all around the world, broaden their world perspective and be inspired to set mathematical goals for themselves that they might not have been previously imaginable or thought possible.

Past participants have gone on to distinguished carriers in mathematics. Most notably, in 2018, Caucher Birkar (born Faraydoun Derakhshani) received the most prestigious award in mathematics, the Fields Medal. In 2000, he participated in the 7th IMC, which was held at UCL. In 2022, a Kyiv-born mathematician, Maryna Viazovska, was also awarded the Fields Medal. She had participated in the IMC as a student four times, in 2002, 2003, 2004 and 2005. Over the past 31 competitions, the IMC has had participants from over 200 institutions from over 50 countries.

For further information and online registration, visit the website at www.imc-math.org.uk. Further details may be obtained from Professor John Jayne (j.jayne@ucl.ac.uk).

AGGITatE 2025: A Conference on Groups, Representations and Cohomology

Location: University of Essex, Colchester
Date: 4–7 August 2025
Website: tinyurl.com/aggitate2025

Funded this year by the LMS, Heilbronn Institute and the INI, *AGGITatE: Algebras, Groups, Geometry, Invariants and related Topics at Essex* brings together the algebra and geometry research communities.

Speakers this year include D. Benson, K. Erdmann, E. Giannelli, J. Greenlees, E. Henke, R. Kessar, S. Law, M. Linckelmann, G. Malle, L. Ruhstorfer, J. Semeraro and C. Vallejo Rodriguez.

Financial support is available, especially for early career researchers.

Deadline for registration with funding: 31 May 2025

Quantum Field Theory with Boundaries, Impurities and Defects

Location: Isaac Newton Institute, Cambridge
Date: 1 September – 12 December 2025
Website: newton.ac.uk/event/bid

This four-month programme is intended to bring physicists and mathematicians together to identify trends, themes, novel applications and new approaches to boundaries, impurities and defects in quantum field theory. In addition to weekly seminars and informal gatherings, the programme includes three periods of more intense activity: a school 8–12 September, a deep-dive workshop 27–31 October, and a final conference 8–12 December.

This event is sponsored by the LMS.

Deadlines: School 4 May 2025 and Conference 3 August 2025

Society Meetings and Events

This calendar lists forthcoming Society meetings. A fuller list is given on the Society's website (lms.ac.uk/events/calendar).

May

- 14 LMS Education Day: Mathematical Journeys
- 14 LMS Seminar on UK/Africa Partnerships
- 14 LMS South West and South Wales Regional Meeting

June

- 4 LMS/Gresham Lecture
- 11 LMS Mathematics Communication Workshops (in person)
- 17 LMS Midlands Regional Meeting
- 20 LMS Hardy Lectureship: Emily Riehl, Aberdeen
- 23 LMS Hardy Lectureship: Emily Riehl, Manchester
- 24 LMS Mathematics Communication Workshops (online)
- 24 LMS Hardy Lectureship: Emily Riehl, Glasgow
- 25 LMS Society Meeting at BMC/BAMC
- 25 LMS Hardy Lectureship: Emily Riehl, Edinburgh
- 27 LMS Hardy Lectureship: Emily Riehl, Cardiff
- 30 LMS Hardy Lectureship: Emily Riehl, Cambridge

July

- 2 LMS Hardy Lectureship: Emily Riehl, Birmingham
- 4 LMS General Meeting and Hardy Lecture
- 7 LMS Hardy Lectureship: Emily Riehl, Bristol

Calendar of Events

This calendar lists other mathematical events. To promote your event in this calendar, send updates or make corrections, please contact calendar@lms.ac.uk.

May

- 5–16 Algebra and Geometry from Africa, Edinburgh
- 12–16 Geometry and Integrability, Edinburgh
- 13 The Troubled Brain: Ageing and Dementia, Professor Alan Goriely FRS, London and online
- 13–16 Introduction to Machine Learning in R, RSS virtual classroom, online
- 17 Scottish Mathematical Council Annual Conference, Stirling
- 18–20 Tashkent International Mathematics Olympiad, Tashkent (Uzbekistan)
- 19–23 Geometric Moduli Spaces, Rigidity, Genericity, Stability, Edinburgh
- 20 Statistical Modelling in Python, RSS Virtual Classroom, online
- 20 Spatial Data Analysis in R, RSS Virtual Classroom, online
- 26–29 NSeaG: Non-Commutative Geometry along the North Sea, Edinburgh

June

- 1–6 Blurring the Lines between Pure and Applied through Mixing, Isle of Skye
- 2–6 Dimensionality Reduction Techniques for Molecular Dynamics, Edinburgh

3–4 Presenting Data, RSS Virtual Classroom, online
9–13 Random Walks, Percolation and Mixing Time, Edinburgh
9–13 Bridging the Gap between Mathematical Modelling of Lava Flows and Field Observations, Edinburgh
10–11 Data Visualisation, RSS Virtual Classroom, online
10–11 Burwalls/Annual Conference for Teachers of Statistics in Medicine and Allied Health Sciences, York
10–11 Mathematical Methods for Wave Problems, Leicester
16–20 20th International Federated Conference on Distributed Computing Techniques, Lille (France)
16–20 Geometric Problems in Linear and Nonlinear PDEs, Isle of Skye
16–27 China–India–UK School in Mathematical Physics, Edinburgh
17 The Deceived Brain: Coding and Illusion, Professor Alan Goriely FRS, London and online
19–20 Diophantine Equations, Combinatorics, Analysis in Number Theory: Emerging Researchers, Edinburgh
21–24 29th International Conference on Circuits, Systems, Communications and Computers, Salerno (Italy)
22–25 34th European Conference on Operational Research, Leeds
23–26 BMC/BAMC Conference, Exeter
23–27 Diophantine Equations, Combinatorics, Analysis in Number Theory, Edinburgh
24–25 UK Conference on Teaching Statistics, Glasgow
23–26 4th IMA Conference on Dense Granular Flows, Cambridge
24–26 IMA Mathematics Anxiety International Conference, Cambridge
30–4 Jul UK–Japan Workshop on Nonlinear PDEs: Singularities and Asymptotic Patterns in Fluids, Chemotaxis and Geometric PDEs, Edinburgh

July

2 The Queer Experience of Mathematics, Loughborough
2–3 Basic Statistics, RSS Training, London
2–4 29th International Conference on Engineering of Complex Computer Systems, Hangzhou (China)
7–8 14th UK Conference on Boundary Integral Methods, Salford
7–8 Interactive Dashboards & Web Apps using R & Shiny, RSS Virtual Classroom, online
7–11 Parallel-in-time Algorithms for Exascale Applications, Edinburgh
8–10 13th IMA International Conference on Modelling in Industrial Maintenance and Reliability, Lorraine (France)
10–11 Heilbronn Annual Conference, Bristol
13–23 Aug Program in Mathematics for Young Scientists, Oxford
14–16 19th International Symposium on Theoretical Aspects of Software Engineering, Limassol (Cyprus)
14–18 Extremal and Probabilistic Combinatorics, Edinburgh
15–16 Automated reports with R, RSS Virtual Classroom, online
15–17 Essentials of Survey Research Design, RSS Virtual Classroom, online
15–18 Spatial Statistics: At the Dawn of AI, Noordwijk (Netherlands)
21–25 Spaces of Tensor Categories, Edinburgh
28–1 Aug Beyond the Horizon: Navigating Turbulence, Irregularity, and Stochasticity in Fluid Dynamics, Edinburgh

August

6–9 MAA MathFest, Sacramento (USA)