Local Arrangements and Programme

Welcome to the Postgraduate Combinatorial Conference 2007 at the University of St Andrews!

We are pleased to see so many of you here, and hope that everyone will have an interesting and enjoyable time at the conference. We are particularly delighted to welcome our invited speakers Dr Carrie Rutherford, Prof. Bruce Sagan and Prof. Robin Wilson.

All of us organisers will be happy to help you with any queries.

Best wishes for the conference and beyond,

Fiona, Debbie, Vincent and Josephine.

Conference

All talks will be held in Lecture Theatre B of the Mathematical Institute. An overhead projector and pens, blackboard space and chalk, as well as a data projector and laptop are available.

Accommodation

Delegate accommodation is provided in McIntosh Hall from Wednesday 6 June until the morning of Saturday 9 June. Please check out by 10 am on Saturday.

Catering

- Breakfast will be served Thursday, Friday and Saturday morning in McIntosh Hall 8 – 9 am.
- Morning and afternoon tea/coffee breaks, as well as the buffet lunches on Thursday and Friday, will take place in room 1A of the Mathematical Institute.
- Please note that the dinners in McIntosh Hall on Wednesday and Thursday last half an hour only, these will be served at 7 and 6 pm respectively.
- After dinner, we will go to the Students' Union. Please bring your student ID card (from your university).
- The conference dinner will be held at the Golf Hotel on Friday. We ask you to be there at 7 pm for the meal at 7.30 pm.

Other Facilities

- Computer and internet access is available in all university computer rooms, e.g. in the Microlab next to Lecture Theatre B in the Mathematical Institute, or in the McIntosh Computer Room (go down the stairs next to the Common Room). You will be issued a username and password upon arrival.
- To find the toilets from the main entrance of the Mathematical Institute, turn right. Male toilets are down the stairs, female toilets just beyond the stairs. The doors to this part of the building are unfortunately locked for re-entry at 5.30 pm so please make sure you don't lock yourself out!

PCC 2008

This is the 18th Postgraduate Combinatorial Conference (PCC). In previous years the conference was held at the following universities:

- PCC 2006 at the University of Glamorgan,
- PCC 2005 at the University of Oxford,
- PCC 2004 at Queen Mary, University of London,
- PCC 2003 at the University of Nottingham.

Why don't you organise next year's PCC? Feel free to speak to any of this year's organisers about what's involved.

Sponsors

We are immensely grateful for the very generous support from the London and Edinburgh Mathematical Societies, the Centre for Interdisciplinary Research in Computational Algebra (CIRCA) at St Andrews University, and the British Combinatorial Committee. Our sponsors' financial contributions have more than halved the registration fees we have had to charge.

Programme Wednesday 6 June

	Chair: Fiona Brunk
16.00 – 16.05	**Welcome by Prof. Nik Ruskuc**
	(Head of Algebra & Combinatorics Research Group at St Andrews)
16.05 – 17.05	**Dr Carrie Rutherford**: Polynomial coprimality — errors and discrepancies
17.15 – 17.35	**Josephine Kusuma**: Orthogonal arrays and t-designs
17.40 – 18.00	**Robert Brignall**: Simplicity in relational structures
19.00 – 19.30	*Dinner at McIntosh Hall*

Thursday 7 June

08.00 – 09.00	*Breakfast*
	Chair: Debbie Lockett
09.30 – 10.05	**Dr Colva Roney-Dougal**: Postdoccing and other matters
10.10 – 10.30	**Haris Aziz**: Efficient algorithm for designing weighted voting games
10.35 – 10.55	**Marianne Fairthorne**: The permutation capacity of graphs
11.00 – 11.25	*Tea & coffee*
	Chair: Adam Watson
11.30 – 11.50	**Rong Gao**: Colouring problems of pseudo-random graphs
11.55 – 12.15	**Viresh Patel**: Partitioning posets
12.20 – 12.40	**Elizabeth Ford**: Counting triangles in evolving random graph models
12.45 – 13.05	**Andreas Distler**: Enumeration of finite semigroups
13.10 – 14.00	*Lunch*
	Chair: Laurence Rackham
14.05 – 14.25	**Sian Jones**: Enumeration of RoDoku
14.30 – 14.50	**Fraser Stewart**: Exact colourings of infinite graphs
15.55 – 15.15	**Fatma Al Kharoosi**: Analysing quaternary codes using binary codes
15.20 – 15.40	**Jason Rudd**: Planar pseudo forests and planar pseudo loop graphs
15.45 – 16.05	*Tea & coffee*
	Chair: Vincent Knight
16.10 – 16.30	**Mareike Massow**: Diametral pairs of linear extensions of a poset
16.35 – 16.55	**Andrew Young**: (k)-ordered Hamiltonian digraphs
17.00 – 17.35	**Dr Stephen Waton**: Opportunities in finance
18.00 – 18.30	*Dinner at McIntosh Hall*

Friday 8 June

08.00 – 09.00	*Breakfast*
	Chair: Josephine Kusuma
09.30 – 10.30	**Prof. Robin Wilson**: 300 years of combinatorics — the legacy of Leonhard Euler
10.35 – 10.55	**Simon Griffiths**: Cycles in oriented graphs
11.00 – 11.30	*Tea & coffee*
	Chair: Atsushi Tateno
11.35 – 11.55	**Laurence Rackham**: Zero sums in higher dimensions
12.00 – 12.20	**Matthias Mnich**: The minimal feedback vertex set problem on tournaments
12.25 – 12.45	**Vincent Knight**: Alternating sign matrices and symmetries
12.50 – 13.10	**Adam Watson**: The combinatorics of rigidity
13.15 – 14.35	*Lunch*
	Chair: Fiona Brunk
14.40 – 15.00	**Debbie Lockett**: Homogeneity and homomorphisms
15.05 – 15.25	**Manuela Heuer**: Similar sublattices of the root lattice
15.30 – 15.50	**Peter Allen**: Partitioning two-coloured complete graphs into monochromatic cycles
15.55 – 16.15	*Tea & coffee*
	Chair: Debbie Lockett
16.20 – 16.40	**Adam Philpotts**: Ore-type conditions for a Hamilton cycle containing a given matching
16.45 – 17.45	**Prof. Bruce Sagan**: Congruences for combinatorial sequences
19.00 for 19.30	*Conference dinner at the Golf Hotel*

Invited Talks on Combinatorics

Dr Carrie Rutherford: Polynomial coprimality — errors and discrepancies

Among the ordered pairs of monic polynomials of degree n over GF(2), exactly half consist of relatively prime polynomials. Proving this, Corteel et al asked for a nice bijection between the relatively prime pairs and the non-relatively-prime pairs. Among the coprime pairs, we focus on a particular subset whose elements we call discrepancies. These exhibit periodicity properties, which we hope to extend to the general problem.

Prof. Robin Wilson: 300 years of combinatorics — the legacy of Leonhard Euler

Where did the combinatorics you study come from? In this talk I outline some topics from the history of the subject, with particular reference to the legacy of Leonhard Euler. Among the topics I shall include are graph theory, design theory, latin squares and the theory of partitions.

Prof. Bruce Sagan: Congruences for combinatorial sequences

We derive congruences for various sequences involving binomial coefficients. In particular, we are able to prove some conjectures of Benoit Cloitre. Surprisingly, the Thue-Morse sequence (from the theory of combinatorics on words) makes an appearance.

Invited Talks on 'Post-PhD Life'

Dr Colva Roney-Dougal: Postdoccing and other matters

In this brief talk I will introduce the main different types of postdoc available in the UK, namely research fellowships, research assistantships and teaching fellowships. We'll see how much supervision you can expect to receive, and how much teaching you're likely to do. I'll cover pay issues, and try to give a feeling of what it feels like to be a postdoc. I'll finish by discussing how likely you are to get a permanent academic job at the end of it all. Questions at the end very much welcomed!

Dr Stephen Waton: Opportunities in finance

Having submitted my PhD on the Combinatorics of Permutations in September 2006, I now work as a commodities strategist at Goldman Sachs in London. I will talk about the jobs available to PhD mathematicians in finance, the opportunities at my company, the differences between working in banking and academia, and what city interviewers expect from postgraduates.

Contributed Talks

Wednesday Session

Josephine Kusuma: Orthogonal arrays and t-designs

We aim to investigate the relationships between an orthogonal array formed by a code and t-designs formed by the supports of the codewords over Rings. In particular, over $\mathbb{Z}_2$ and $\mathbb{Z}_4$.

Robert Brignall: Simplicity in relational structures

Many of the combinatorial structures we look at – posets, graphs, tournaments, permutations, and so on – fall under the umbrella of a much more general context, namely that of relational structures. A *relational structure* consists of a *ground set* of elements equipped with a language of one or more relations. We may regard many of the well-known combinatorial objects as relational structures. For example, a permutation π on n points is simply the set $[n]$ with two linear orders, namely the usual $<$ ordering $(1 < 2 < \ldots < n)$ and a second $\prec$ order, for which $i \prec j$ if and only if $\pi(i) < \pi(j)$.
An *interval* in a relational structure is a set of elements from the ground set for which every pair of elements in the interval have exactly the same relations with the elements outside the interval. Accordingly, every singleton set is an interval, as is the whole ground set. Every other interval is said to be a *proper* interval, and a structure with no proper intervals is said to be *simple*. We may well be familiar with this concept in many of the specific areas of study – for example, "simple" graphs are more commonly referred to as *indecomposable* or *prime*.
I will talk about what we can say using simplicity both in the general setting of relational structures, and in the differences between particular structures. For example, on the one hand, every type of relational structure can be broken into its elemental simple components using the *substitution decomposition*, while on the other hand, there is a great disparity between the asymptotic enumeration of simple objects between different structures. For example only a fraction of permutations of length n are simple, but "almost all" graphs on n vertices are indecomposable.

Thursday Session 1

Haris Aziz: Efficient algorithm for designing weighted voting games

Weighted voting games are mathematical models, used to analyse situations where voters with variable voting weight vote in favour of or against a decision.

They have been applied in various political and economic organizations for structural or constitutional purposes. Prominent examples include the United Nations Security Council, the International Monetary Fund and especially the European Union. Weighted voting games are also used in joint stock companies where each shareholder gets votes in proportion to the ownership of a stock. The calculation of voting powers of players in a weighted voting game (which is NP-hard in all well known cases) has been extensively researched in the last few years. However, the inverse problem of designing a weighted voting system with a desirable distribution of power has received less attention. We present an elegant and efficient algorithm to compute a corresponding integer weight vector for a given vector of *Banzhaf power indices*. This is an extension of the work on the method of generating functions to compute voting power indices. The algorithm uses interpolation and requires minimal number of iterations. It is designed as a ready-made tool to be used by economists and political scientists in their analysis of weighted voting games. This algorithm has better performance than any other known to us. We have used our algorithm to also design egalitarian two-tier weighted voting games. This has an application in the design of the voting system of the European Union. Our algorithm also aids in finding a representative weighted voting game for a multiple weighted voting game. We have also provided a survey of designing weighted voting games and proposed further directions for research. Experiments with variations of the algorithm also promise to give better insight into the nature of the relationship between voting weights and corresponding voting powers.

Marianne Fairthorne: The permutation capacity of graphs

Given a graph G with vertex set $V \subseteq \mathbb{N}$, two permutations $x_1 x_2 \ldots$ and $y_1 y_2 \ldots$ will be considered adjacent using G if $x_i y_i \in E(G)$ for some i. We let $\rho(G,n)$ denote the maximum clique number over graphs whose vertices are permutations on n natural numbers, and which are adjacent if these permutations are adjacent using G. Then the permutation capacity, $\rho(G)$, of G is defined by

$$\rho(G) := \limsup_{n\to\infty} \frac{1}{n} \log_2 \rho(G,n).$$

We look at the problem of determining the permutation capacity of an infinite path and improve existing bounds, and give bounds for the permutation capacity of other infinite graphs.

Thursday Session 2

Rong Gao: Colouring problems of pseudo-random graphs

We discuss various colouring problems for particular pseudo-random graphs, emphasising on de bruijn graphs.

Viresh Patel: Partitioning posets

Let $P = (X, \prec)$ be a poset. A down-set of P is a subset, $A \subseteq X$, such that if $a \in A$ and $b \prec a$ in P, then $b \in A$. For A a down-set of P and $B = X \backslash A$, define

$$E(A, B) = \{(a, b) : a \in A, b \in B, a \prec b\}.$$

This defines an analogue of cuts for posets. In this talk we address the following natural questions: how large can $|E(A, B)|$ be and how difficult is it (computationally) to maximise $|E(A, B)|$?

Elizabeth Ford: Counting triangles in evolving random graph models

The Barabási-Albert random graph model is a popular choice for modelling scale-free networks. We study the asymptotic distributions of the number of triangles in two related evolving random graph models. The first model attaches edges to existing vertices uniformly at random, while the second evolves by preferential attachment. An application of Stein's method gives us a normal approximation for the number of triangles in the first model. For the preferential attachment model we give recursive formulae for the expected number of triangles at step n.

Andreas Distler: Enumeration of finite semigroups

The topic of this talk arises from the determination of finite semigroups. A semigroup is a set with an associative binary operation. Examples are $\mathbb{N}$ under addition, $\mathbb{Z}_n$ under multiplication, the multiplicative part of a ring, all continuous mappings of a metric space under composition and all groups.
In contrast to the case of groups, where all groups with up to 2015 elements have been constructed, only the semigroups with up to 8 elements are known. There are $1, 843, 973, 431$ of them. However most semigroups S have a very simple structure. That is, the product of any three elements in S is 0 and $0x = x0 = 0$ for all $x \in S$. The name for such semigroups is 3-*nilpotent*. Almost 99.4% of the semigroups with 8 elements are 3-nilpotent.

In this talk I will present an algorithm for computing the exact number of 3-nilpotent semigroups. This yields a very good estimate for the total number of semigroups with n elements.

Thursday Session 3

Sian Jones: Enumeration of RoDoku

A RoDoku puzzle is a puzzle based on a 6x6 puzzle made up of 6 3x2 grids (a smaller size SuDoku puzzle) with some digits in place, the aim of which is to complete the grid so that all of the numbers 1 to 6 are contained in all the rows, columns and mini-grids. Some work has been done by Pettersen (2005) to discover that the total number of possible RoDoku grids (from blank puzzles) is 28,200,960, this has been achieved using programming techniques to search every possible grid. In 2005 Felgenhauer B. and Jarvis F. found the total number of grids for a 9x9 SuDoku to be 6,670,903,752,021,072,936,960. They achieved this result using some combinatorial proof and some enumeration by computer. The combinatorial results have been further developed here to become a form of design called a Semi-Orthogonal Latin Design which has been applied to the 6x6 RoDoku; this and other proofs will be used to prove that the count by Pettersen (2005) is accurate (using some computer aided enumerations) and to prove certain upper and lower bounds for this count.

Fraser Stewart: Exact colourings of infinite graphs

An exact colouring is a proper vertex colouring of a graph such that for every pair of colours there is exactly one edge whose end vertices have those colours. It has been shown that the problem of finding graphs with exact colourings is equivalent to finding a graphs harmonious chromatic number and is therefore NP-complete. I will be looking at finding the classes of infinite graphs which have an exact colouring, and investigating whether or not it is possible to embed NP-complete problems into any class of infinite graph.

Fatma Al Kharoosi: Analysing quaternary codes using binary codes

For a quaternary code C of length n, define a pair of binary codes $\{C_1, C_2\}$ as:

- $C_1 = C \pmod{2}$
- $C_2 = h(C \cap 2(\mathbb{Z}_4)^n)$

where h is a bijection from $2\mathbb{Z}_4$ to $\mathbb{Z}_2$ mapping 0 to 0 and 2 to 1 and for the extension to a map acting coordinatewise. Here $C_1 \leq C_2$

Fix two binary codes of length n, with $C_1 \leq C_2$. Let $\mathcal{C}$ be the set of all quaternary codes giving rise to $\{C_1, C_2\}$ as above. I will discuss a method of analysing the set $\mathcal{C}$ using the pair $\{C_1, C_2\}$.

Jason Rudd: Planar pseudo forests and planar pseudo loop graphs

Given a connected graph Γ, the Tutte Polynomial

$$T(\Gamma; x, y) = \sum_{D \subseteq E} (x-1)^{\rho\Gamma - \rho D}(y-1)^{|D| - \rho D}$$

can be used to count the spanning trees, forests, connected spanning subgraphs and subgraphs of Γ via

$$\begin{aligned} \#\text{ spanning trees} &= T(\Gamma; 1, 1) \\ \#\text{ forests} &= T(\Gamma; 2, 1) \\ \#\text{ connected spanning subgraphs} &= T(\Gamma; 1, 2) \\ \text{total }\#\text{ subsets of } E &= T(\Gamma; 2, 2) \end{aligned}$$

This is essentially because the only graphs for which the only flow is the all zero flow are forests, and that the only graphs for which the only tension is the all zero tension are those in which every edge is a loop (contracting all of the edges of a connected spanning subgraph leaves such a graph).

If $G \leq \mathsf{Aut}(\Gamma)$ is an automorphism group, it is not so simple to count the spanning trees, forests, connected spanning subgraphs and subgraphs of Γ fixed by every $g \in G$, but the problem can be reduced to classifying edge graphs for which G is transitive on the edges of Γ; either which are not forests but for which the only flow fixed by every $g \in G$ is the all zero tension, or which are not made up entirely of loops but for which the only tension fixed by every $g \in G$ is the all zero tension. These we call *(Transitive) Pseudo Forests* and *(Transitive) Pseudo Loop Graphs*.

Classifying these graphs leaves a couple of open problems, but they can be completely classified in the planar case.

Thursday Session 4

Mareike Massow: Diametral pairs of linear extensions of a poset

Given a poset P, I consider pairs of linear extensions of P with maximal distance. The distance of two linear extensions L_1, L_2 is the number of pairs of

elements of P appearing in different order in L_1 and L_2. A diametral pair maximizes the distance among all pairs of linear extensions of P.
Diametral pairs were introduced by Felsner and Reuter in 1999; they are of interest because their intersection forms a minimal two-dimensional extension of P. Finding a two-dimensional poset which is close to a given one is a promising task since a number of hard problems is efficiently solvable in the two-dimensional case.
My aim is to characterize the extremal linear extensions, i.e., those which are contained in a diametral pair. I suggest a connection to critical pairs: Two incomparable elements u, v of P form a critical pair (u, v) if Pred$(u) \subseteq$ Pred(v) and Suc$(v) \subseteq$ Suc(u). A critical pair is reversed in a linear extension L if $v < u$ holds in L.
I conjecture that every extremal linear extension reverses a critical pair of P. In this talk, I will present partial results (joint work with Stefan Felsner) and a related concept: The graph of linear extensions of a poset. The vertices of this graph are formed by all linear extensions of P, and two vertices are adjacent iff the corresponding linear extensions differ only by an adjacent transposition.

Andrew Young: k-ordered Hamiltonian digraphs

A digraph $\overrightarrow{G}$ is k-ordered Hamiltonian if for every sequence $s_1, s_2, \ldots, s_k$ of distinct vertices of $\overrightarrow{G}$ there is a Hamilton cycle that encounters $s_1, s_2, \ldots, s_k$ in this order. The main result of this talk is that every digraph $\overrightarrow{G}$ with sufficiently large order n and minimum in- and outdegree $\delta^-(\overrightarrow{G}), \delta^+(\overrightarrow{G}) \geq \lceil \frac{n+k}{2} \rceil - 1$ is k-ordered Hamiltonian.

Friday Session 1

Simon Griffiths: Cycles in oriented graphs

It is known that every simple graph with $n^{3/2}$ edges contains a four cycle. On the other hand it is easy to construct an oriented graph which has many edges but contains no (oriented) four cycle. Consider the oriented graph G with vertex set $V = \{1, ..., n\}$ and an edge ij whenever $i < j$. Then G has $\binom{n}{2}$ edges (the most possible) but contains no four cycle. We notice that G has an extreme bias in it's orientation. We can find subsets $A, B \subset V$ with many edges from A to B but none returning. We show that only 'biased' oriented graphs such as this can avoid containing four cycles. We also show that (up to multiplication by a constant) our result is best possible, and we discuss a number of related questions.

Friday Session 2

Laurence Rackham: Zero sums in higher dimensions

Let $s(\mathbb{Z}_n^d)$ be the least number so that for any sequence of $s(\mathbb{Z}_n^d)$ elements in $\mathbb{Z}_n^d$ (repetition allowed) there are n elements whose sum is $0 \in \mathbb{Z}_n^d$. A famous theorem of Erdős, Ginzburg and Ziv (1961) states that $s(\mathbb{Z}_n) = 2n - 1$ and recently Reiher (2007) has shown that $s(\mathbb{Z}_n^2) = 4n - 3$.
We study the problem in higher dimensions, examine the connection with maximal affine caps and look at the problem in the more generalised setting of finite Abelian groups.

Matthias Mnich: The minimal feedback vertex set problem on tournaments

A tournament is a complete graph with orientations for all edges. A minimal feedback vertex set of a tournament is a subset of the vertices such that its deletion leaves a maximal induced acyclic subtournament. For a tournament T on n vertices, its number $m(T)$ of minimal feedback vertex sets can be exponential in n. This paper improves lower and upper bounds on $m(T)$. We first construct a tournament of order n with $21^{\frac{n}{7}} \approx 1.54486^n$ many minimal feedback vertex sets. We then show that all tournaments of order n have at most 1.68179^n many minimal feedback vertex sets. From this we derive that the existence of a feedback vertex set of order at most k is decidable in time $O^*(1.68179^k)$. A minimum feedback vertex set can thus be found in time $O^*(1.54866^n)$.

Vincent Knight: Alternating sign matrices and symmetries

Alternating sign matrices (ASMs) are matrices that have been studied for over 20 years. Notably solving the conjectures related to their counting functions. I have starting working on the symmetries of ASMs and in this talk plan to illustrate some of the arguments leading to counting functions. Also there is a connection between magic squares and ASMs that I shall illustrate.

Adam Watson: The combinatorics of rigidity

A graph G can be realised as various kinds of framework in $\mathbb{R}^d$, and their rigidity or flexibility is a natural area of mathematical interest. Combinatorial rigidity is concerned with how the combinatorial structure of the graph G affects the ridigity or flexibility of these frameworks. Applications arise in computational biology and pharmacology, nanotechnology, and the design of wireless networks.

Friday Session 3

Debbie Lockett: Homogeneity and homomorphisms

A relational structure S (e.g. a graph, or poset) is *homogeneous* if any isomorphism between finite substructures of S can be extended to an automorphism of S. This notion was first introduced by Fraïssé in about 1950, who was interested in structures with lots of symmetry. Less formally, the definition says that a structure is homogeneous if any local symmetry is in fact global. Homogeneity has been widely studied, and in 2004 Cameron and Nešetřil suggested a weakening of the notion by considering homomorphisms and monomorphisms instead of isomorphisms. I will present an outline of the progress I have made looking at these generalisations of homogeneity - some results, some conjectures, and some of the many open questions.

Manuela Heuer: Similar sublattices of the root lattice A_4

A linear map S of $\mathbb{R}^d$ is called a similarity, if $\langle Su, Sv\rangle = c\langle u, v\rangle$ for all $u, v \in \mathbb{R}^d$ and a constant $c > 0$. Any lattice $\Gamma \subset \mathbb{R}^d$ possesses sublattices that are images of Γ under similarities. These sublattices, which have finite index in Γ, are called similar sublattices (SSLs) of Γ. How many distinct SSLs are there of each index? This question has already been answered for many lattices in dimensions $d \leq 4$. However, for the root lattice $A_4 \subset \mathbb{R}^4$ we have just recently found the answer which I will present in my talk.

Peter Allen: Partitioning two-coloured complete graphs into monochromatic cycles

A conjecture due to Lehel states that for any two-edge-coloured complete graph on n vertices there exist vertex-disjoint cycles of opposite colours which cover all the vertices of the graph. We show that the conjecture holds when n is sufficiently large.

Friday Session 4

Adam Philpotts: Ore-type conditions for a Hamilton cycle containing a given matching

Let G be a finite simple graph and let $\sigma_2(G) = \min\{d(u) + d(v) : uv \notin E(G)\}$. A *matching* is a set of pairwise disjoint edges, and a k-*matching* is a matching with k edges. This talk addresses a question which was investigated over 20

years ago but never completely settled: what bounds on $\sigma_2(G)$ ensure that every k-matching in G is contained in a Hamilton cycle?
It turns out that the sharp bounds are $\sigma_2(G) \geq \max\{2\lceil\frac{1}{2}(n+k)\rceil - 1, n+1\}$ if $k \leq \frac{1}{3}(n-1)$ or $\sigma_2(G) \geq \max\{2n-2k-1, n+1\}$ if $k \geq \frac{1}{3}(n-1)$. We discuss some extremal counter examples, and give some ideas from the proof that the latter bound on $\sigma_2(G)$ suffices; this proof also shows that if $\sigma_2(G) \geq n+1$ then any matching and single vertex are contained in a cycle of G. All work is joint with Douglas Woodall.

Participants

Fatma Al Kharoosi	Queen Mary, University of London	falk@maths.qmul.ac.uk
Peter Allen	London School of Economics	peter@maths.lse.ac.uk
Haris Aziz	University of Warwick	haris.aziz@warwick.ac.uk
Jonathan Bagnall	University of St Andrews	jbagnall@mcs.st-andrews.ac.uk
Robert Brignall	University of St Andrews	robertb@mcs.st-and.ac.uk
Fiona Brunk	University of St Andrews	fbrunk@mcs.st-and.ac.uk
Hannah Coutts	University of St Andrews	hcoutts@mcs.st-and.ac.uk
Andreas Distler	University of St Andrews	andreas@mcs.st-andrews.ac.uk
Marianne Fairthorne	London School of Economics	marianne@maths.lse.ac.uk
Elizabeth Ford	University of Oxford	ford@stats.ox.ac.uk
Rong Gao	University of Essex	rgao@essex.ac.uk
Simon Griffiths	University of Cambridge	sg332@cam.ac.uk
Manuela Heuer	Open University	m.heuer@open.ac.uk
Robin Hughes-Jones	Royal Holloway, University of London	r.j.hughes-jones@rhul.ac.uk
Sian Jones	University of Glamorgan	siankjones@hotmail.com
Vincent Knight	University of Cardiff	knightva@cf.ac.uk
David Knipe	University of Leeds	davidk@maths.leeds.ac.uk
Josephine Kusuma	Queen Mary, University of London	j.kusuma@qmul.ac.uk
Debbie Lockett	Queen Mary, University of London	d.lockett@qmul.ac.uk
Victor Maltcev	University of St Andrews	victor@mcs.st-and.ac.uk
Mareike Massow	Technische Universität Berlin	massow@math.tu-berlin.de
Matthias Mnich	Technische Universiteit Eindhoven	m.mnich@tue.nl
Viresh Patel	London School of Economics	v.patel1@lse.ac.uk
Yann Peresse	University of St Andrews	yperesse@mcs.st-andrews.ac.uk
Adam Philpotts	University of Nottingham	pmxarp@nottingham.ac.uk
Laurence Rackham	Royal Holloway, University of London	l.rackham@rhul.ac.uk
Jason Rudd	Queen Mary, University of London	jasondanielrudd@yahoo.co.uk
Tony Samuel	University of St Andrews	as57@st-andrews.ac.uk
Fraser Stewart	University of Dundee	fraserstewart@computing.dundee.ac.uk
Atsushi Tateno	University of Oxford	atsushi.tateno@merton.ox.ac.uk
Emil Vaughan	Queen Mary, University of London	e.vaughan@qmul.ac.uk
Adam Watson	Queen Mary, University of London	a.watson@qmul.ac.uk
Andrew Young	University of Birmingham	younga@for.mat.bham.ac.uk