

Editorial

Ursula Martin's article in the last issue was particularly topical in celebrating the impact of mathematics upon society. Although I have yet to see *Hidden Figures*, I have read the book by Margot Lee Shetterly that inspired this film. It is astonishing that the brilliant mathematicians – who performed the extensive analyses and laborious calculations that enabled the USA to fly supersonically, journey through space and visit the moon – were not properly recognised for 50 years.

These forgotten geniuses were known simply as computers and included Dorothy Vaughan, Katherine Johnson and Mary Jackson. At least their dedication and achievements have finally been acknowledged. The accomplishments of many other gifted mathematicians are similarly hidden from public view due to their sensitive nature, particularly in defence as evidenced by James Moffat's remarkable recollections that also appeared in April's issue of *Mathematics Today*.

I hope that you have visited the IMA's fabulous new website. There is plenty to explore, including puzzles, careers, jobs, policies, newsletters, articles, publications, awards, conferences, branches, workshops and access to the newly upgraded database via myIMA. Among these webpages, you will find information about the recent inaugural conference on *Mathematics of Operational Research* hosted jointly with the OR Society and the imminent *IMA Festival Greenwich Maths Time*.

The IMA-LMS Christopher Zeeman Medal was awarded to Rob Eastaway in March, for excellence in mathematical promotion and public engagement. Rob's article based on his lecture appears in this issue (page 94). This year's joint IMA Gold Medal winners are Tony Croft (Loughborough University) and Duncan Lawson (Newman University) in recognition of their outstanding contributions to mathematics and its applications. They will talk in London on 29 June about 25 years of improving mathematics education, so many congratulations to them on this wonderful achievement (page 107).

This year's prestigious Abel Prize has just been awarded to Yves Meyer (ENS Paris-Saclay), for developing the mathematical theory of wavelets (page 92). The Association for Computing Machinery is presenting its Turing Award to Tim Berners-Lee (University of Oxford and Massachusetts Institute of Technology), for inventing the World Wide Web and associated tools used by billions of people every day. Mathematics contributed much to this phenomenal impact. Also, the Canadian Mathematical Society is awarding its Krieger-Nelson Prize to Stephanie van Willigenburg (University of British Columbia), for contributions to the field of algebraic combinatorics.

Back in the UK, some new money is appearing in England and Wales. The Bank of England introduced £5 polymer banknotes last September and plans to introduce similar £10 notes this September, featuring much-loved novelist Jane Austen on the bicentenary of her death. Pleasingly, a commemorative 50p coin will also be released to celebrate Isaac Newton's substantial influence on mathematics, physics and minting.

A new twelve-sided £1 coin appeared in March, partly to counter the problem that about one in 30 of the old coins was counterfeit. Attractive as this coin is, it does not have the useful property of constant diameter that circular coins possess. This can be an important authenticating factor for parking meters,



vending machines, supermarket trolleys and other automated payment devices. Instead, it approximates a regular convex curvilinear dodecagon, similar to an old threepenny bit, and its diameter varies from 23.03 mm to 23.43 mm.

In contrast, the 20p and 50p coins rather surprisingly have constant widths despite being non-circular, as they approximate Reuleaux heptagons. The width-preserving property of Reuleaux polygons is quite impressive. Figure 1(a) illustrates how to construct the simplest case using three circular arcs centred at the vertices of an equilateral triangle. Reuleaux triangles were studied by Leonardo Da Vinci and Leonhard Euler, and appear in Gothic architecture, steam engines and film projectors.

This construction method applies only to polygons with odd numbers of sides, which explains why the new twelve-sided £1 coin has variable diameter. More generally, Figure 1(b) shows how to construct a curvilinear polygon of constant width that avoids tangential discontinuities at the vertices. This simplest case connects six circular arcs and also derives from an equilateral triangle. As above, the fundamental polygon must have an odd number of sides.

An obvious generalisation to three dimensions is the Reuleaux tetrahedron, defined by the intersections of four spheres centred at the vertices of a regular tetrahedron. Surprisingly, the diameter of this surface varies, though related solids with constant width do exist. One is a surface of revolution formed by rotating a Reuleaux triangle about a line of symmetry. Another is a Meissner tetrahedron formed by prescriptively smoothing three edges of a Reuleaux tetrahedron. Amazingly, these solids that enable parallel planes to glide smoothly and equidistantly are currently manufactured and sold by Maths Gear (<https://mathsgear.co.uk>).

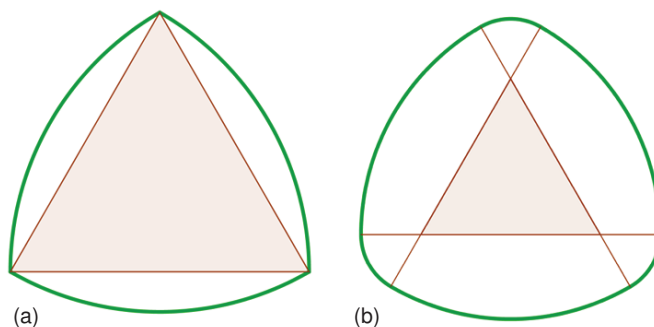


Figure 1: (a) Reuleaux triangle and (b) curvilinear hexagon of constant width. Both figures were generated using GeoGebra.

Now, can you name the world's oldest international sporting trophy? First contested in 1851, 26 years before test cricket, it is the America's Cup and Bermuda will host its 35th challenge during 17–27 June.

This is a tremendously exciting sailing competition that involves the best of 13 match races between just two yachts, the defender (USA as current holder) and the challenger. The latter is the winner of the Louis Vuitton Cup, decided by preliminary races during May and June. This year's five potential challengers represent France, Great Britain, Japan, New Zealand and Sweden. Although preliminary racing yachts are identical, some flexibility encourages creative innovation for America's Cup yachts.

The competition has seen phenomenal advances in technological design, though two of the most important impacts upon speed through the water were discovered several centuries before these races began. The first was the introduction of fore-and-aft rigging as a replacement for square rigging, so enabling much better progress towards the wind. The second was the introduction of multihull boats as replacements for monohull boats; providing more stability while requiring less draft. Even so, the America's Cup has used catamarans only since 2010.

Aerodynamic and hydrodynamic resistances have reduced, as have weights of superstructure, hulls, masts and keels. Aerofoils (rigid sails) have replaced fabric sails, helping to lift the boats and increase speed through the water in all directions. The most recent significant development was the introduction of hydrofoils, which raise the 15-metre long boats almost completely out of the water and enable them to sail at twice the speed of the wind. During trials in 2012, a New Zealand team managed to sail at a speed of 40 knots in a breeze of just 17 knots (1 knot is about 1.15 mph).

The fastest sailing record was set by Australian Paul Larsen in 2012, who achieved an average speed of 65 knots in a 25-knot wind over a 500-metre course, even beating the fastest kitesurfing record of 56 knots. His foiling catamaran was a radical innovation, with one hull forming the cockpit and the other supporting the sail, though his astonishing achievement also required considerable skill and physical strength. Such designs would be of little use for America's Cup races, which require good speeds at all points of sailing.



Land Rover BAR's R1 skippered by Sir Ben Ainslie sailing on the Great Sound in Bermuda. © Harry KH | Land Rover BAR

Yet faster, the current world water speed record is an incredible 276 knots, achieved in a wooden boat that was built and piloted by Australian Ken Warby nearly 40 years ago. Shamelessly benefitting from an aircraft's turbojet engine, this is considerably faster than the speeds achieved by modern Formula One motor cars. Sadly, two subsequent official attempts at breaking this record resulted in fatal crashes.

June's issue of *Mathematics Today* contains features on cracking in nuclear graphite, orbital origins, algebra, conics and cubics, along with our regular columns that include *Urban Maths* and *A Doctor Writes*. Alan Champneys' second *Westward Ho!* is about *Mathematics on the Beach*, so slap on your lotion, sunglasses and hat, find a deckchair and enjoy!

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puzzle

Enigmaths 170: Pandigital Triangulars by ZAG

In this puzzle featuring triangular numbers (those of the form $n \times (n+1)/2$ for some integer n), the top and bottom grid rows between them use all the digits from 0 to 9. As usual, no answer starts with a zero.

Across

1. triangular
2. triangular
4. see 2dn
5. reverse(7ac)
7. square
8. $7ac - 8dn$
9. triangular
10. triangular

Down

1. square
2. $4ac + \text{digit product}(4ac)$
3. triangular
4. triangular
6. square
8. see 8ac

1		2	3	
	4		5	6
7		8		
9			10	

Puzzle solution is on the inside back cover.