

MATHEMATICS

2018/2019

WARWICK
THE UNIVERSITY OF WARWICK



93%

OF OUR STUDENTS SAID THAT OUR DEGREE IS INTELLECTUALLY STIMULATING IN THE NATIONAL STUDENT SURVEY 2016



ONE OF ONLY FOUR UK MATHEMATICS DEPARTMENTS IN THE

WORLD TOP 50



IN THE 2014 RESEARCH EXCELLENCE FRAMEWORK, MORE THAN

90%

OF OUR RESEARCH WAS RATED AS 'WORLD LEADING' OR 'INTERNATIONALLY EXCELLENT'



WARWICK MATHEMATICS AND STATISTICS IS THE RECIPIENT OF THE QUEEN'S ANNIVERSARY PRIZE

FOR HIGHER AND FURTHER EDUCATION



OVER

90%

OF OUR STUDENTS ARE IN PROFESSIONAL / MANAGERIAL JOBS WITHIN SIX MONTHS OF GRADUATING*

*AVERAGING OF UNISTATS FIGURES FOR THE BSc AND MMath DEGREES



£27,600

IS THE AVERAGE SALARY ACHIEVED BY OUR STUDENTS

WITHIN SIX MONTHS OF GRADUATING*

*DESTINATION OF LEAVERS FROM HIGHER EDUCATION (DLHE) SURVEY 2014/15

WHY STUDY MATHEMATICS?

For Beauty and Pleasure. Mathematics is a monument of human imagination and intuition guided by precision. It is sometimes challenging, but the challenge is like ascending a hill to admire an enchanting vista. It is often also just plain fun.

To make a difference to the world. Mathematical techniques and talent are employed to solve real-world problems across industry, business and government. Take the internet, medical imaging, weather forecasting, encryption, the human genome project, data compression... none of these would be possible without mathematics.

To start the journey towards a rewarding career. Our mathematics graduates are in high demand and enjoy a huge choice of fulfilling and creative opportunities. Working in computing, finance, government and education, they conduct research into machine learning, tomography, data systems and financial products.

"The object of pure mathematics is unfolding the laws of human intelligence."

James Joseph Sylvester

"The quantified contribution of mathematical science research to the UK economy is estimated to be approximately 2.8 million in employment terms and £208 billion in terms of GVA contribution."

Measuring the Economic Benefits of Mathematical Science Research, a report for the Engineering and Physical Sciences Research Council (EPSRC) and Council for Mathematical Sciences (CMS).

WHY MATHS AT WARWICK?

+ Choice and Depth

We offer a huge number of exciting modules allowing you to develop and pursue your interests within mathematics. Many 3rd and 4th year modules offer a glimpse of the latest developments in mathematics research.

+ Flexibility of Course Composition

You are free to do 100% maths if you prefer. But we also offer the opportunity to choose options from several other world-class departments at Warwick. This provides flexibility to tailor your degree to suit your interests, and also your potential career.

+ Strong Support for Teaching and Learning

The timetable is full and the topics challenging, but the

support you will receive will be equally as intense. We want you to have a fulfilling university experience. Your personal tutor facilitates your academic progress and looks out for your well-being, and lectures are supported by supervisions with postgraduate students.

+ Strong peer support

The whole set-up of our department - the breakout areas and common spaces - are all geared to you sharing, collaborating and making life-long friendships.

+ Our international reputation

As a centre of excellence we attract research mathematicians from all over world. We offer an intellectually stimulating atmosphere that few institutions rival.

“You have to be prepared to work hard but once you’re OK with that it’s the most exciting place to study Maths.”

Adday Heller, 2nd year MMaths with Study Abroad student and Women in Maths representative



YOUR WAY IN...

MAT, TMUA and STEP

We encourage (but do not require) applicants to sit one of the following admissions tests:

- **MAT** - Mathematics Admissions Test
- **TMUA** - Test of Mathematics for University Admission
- **STEP** - Sixth Term Examination Paper

Preparing for one of these tests will help you develop your problem solving skills and deepen your understanding of mathematics.

Here are some points you should bear in mind:

- The MAT and TMUA are in November
- STEP is in June. There are three STEP papers and we accept all three
- See our MAT, TMUA and STEP page for helpful resources and links explaining how to register for these tests

warwick.ac.uk/maths/admissions/ug/aeastep

With A-Levels

Applicants for 2018 entry who take MAT or TMUA in November 2017 and do well are likely to receive the following offer:

A* (Maths), A* (Further Maths), A

Applicants for 2018 entry who do not sit either of the MAT or TMUA (or do not do well in these tests) are likely to receive the following offer:

- Either A* (Maths), A* (Further Maths), A, plus grade 1 in any STEP paper
- or A* (Maths), A* (Further Maths), A*
- or A* (Maths), A* (Further Maths), A, A

We expect to make offers to most Year 13 applicants who are predicted A* A A or higher.

Note:

- We don't interview but we do invite you to attend an offer holder open day to see the department, and meet staff and current students.
- General Studies and Critical Thinking do not count towards A-Level requirements.

YOUR WAY IN...

with the International Baccalaureate

Applicants for 2018 entry who take MAT or TMUA in November 2017 and do well are likely to receive the following offer:

- 39 points overall, with 6,6,6 in HL subjects, including HL Maths.

Applicants for 2018 entry who do not sit either of the MAT or TMUA (or do not do well in these tests) are likely to receive the following offer:

- either 39 points overall, with 6,6,6 in HL subjects, including HL Maths, plus grade 1 in any STEP paper
- or 39 points overall, with 7,6,6 in HL subjects, including HL Maths.

We expect to make offers to most IB applicants who are predicted 38 points overall with 6 in HL Maths.

if you live outside the UK

The University of Warwick is home to around 7,000 international students from over 140 countries, and the Mathematics staff are recruited worldwide and contribute to the Institute's cosmopolitan outlook. We warmly welcome applications from international students who share our passion for mathematics. Typical offers for 30 international qualifications can be found at

warwick.ac.uk/maths/admissions/ug/otherquals

If your qualification is not listed, or if you have any queries about entrance requirements, please contact us at mathsadmissions@warwick.ac.uk

The University of Warwick International Office can also offer help and advice.

warwick.ac.uk/study/international/

English language: All applicants must satisfy the University's Admissions Requirement, including a minimum level of competence in the English language.

warwick.ac.uk/study/undergraduate/apply/language

MATHEMATICS DEGREES

We offer two single-subject Mathematics degrees:

G100: Mathematics BSc

This is a 3-year maths degree that is broad and highly flexible.

G103: Master of Mathematics (MMath)

This 4-year degree is a natural route for those contemplating a mathematical career in industry, business or academia.

Course Structure for Maths BSc:

- 1st year: 8 core modules (75% of normal load).
- 2nd year: 5 core modules plus essay (55% of normal load).
- 3rd year: no core, but do at least 50% maths.

The remaining modules can be chosen from mathematics or one of many subjects.

Course Structure for MMath:

- Same core as BSc.
- Students must do at least 75% maths each year.



"The Mathematics degree at Warwick is challenging, but as a result it is extremely rewarding. As soon as you have understood one topic/module, the next one is never too far away! The flexibility to pursue the areas of Mathematics that you enjoy is extremely helpful - being able to tailor your degree to what you are most interested in allows you to get the most from your degree."

Benjamin Li, Maths BSc 2011-2014,
Now Associate Consultant, Aon Hewitt

Three or Four Years Maths?

- Maths BSc and MMath have the same entrance requirements.
- Maths BSc and MMath share the same core in the 1st year.
- It is easy to switch from Maths BSc to MMath until the end of the 1st year.
- It is easy to switch from MMath to Maths BSc until the end of the 3rd year.
- If you're struggling to decide pick either and you can change your mind later.

Teaching: Most of our teaching is through lectures. These are typically 3 hours per week for each module, and delivered by a member of academic staff. Undergraduates usually take around five modules in each of Term 1 and Term 2. Term 3 is mostly for revision and examinations.

Taking a gap year before study?

We welcome applicants who wish to take a 'gap year' between school and university. Just achieve your admissions offer and your place will be reserved.

Modules offered in 1st year ¹

1st Year Core Maths Modules:

Foundations, Differential Equations, Introduction to Abstract Algebra, Analysis I, Analysis II, Linear Algebra, Maths by Computer, Geometry and Motion, Probability A.

1st Year Optional Modules

- **From Mathematics and Statistics:** Introduction to Geometry, Experimental Maths, Probability B, Programming for Scientists, Statistical Laboratory.
- **From Physics:** Classical Mechanics and Special Relativity, Electricity and Magnetism, Introduction to Astronomy, Introduction to Particle Physics, Quantum Phenomena.
- **From Computer Science:** Design of Information Structures, Discrete Mathematics and its Applications 2.
- **From Philosophy:** Issues in Philosophy, Descartes and Mill, Logic I, Doing Philosophy of Mathematics, Elements of Scientific Methods.
- **From Economics:** Introduction to Quantitative Economics.
- **From the Warwick Business School:** Mathematical Programming I.
- **The Language Centre** at Warwick offers academic modules in Arabic, Chinese, French, German, Japanese, Russian and Spanish at a wide range of levels.

“Having a Maths degree puts you in great stead for any job, but definitely have a go at a couple of the optional subjects from other departments even if you want a pure Maths degree. I found the business and teaching modules not only introduced me to some great friends I still keep in touch with, but also give my CV relevant skills for business-related careers.”

Lorna Flint,
Maths BSc 2010–2013

¹ The list of modules varies from year to year and is subject to changes in curriculum and staff research interests. This list is accurate for the 2016–2017 academic year.

Modules offered in 2nd year ²

2nd Year Core Maths Modules:

Vector Analysis, Advanced Linear Algebra, Analysis III, Groups and Rings, Differentiation, Second Year Essay.

2nd Year Optional Modules

- **From Mathematics and Statistics:** Combinatorics, Geometry, Introduction to Partial Differential Equations, Metric Spaces, Numerical Analysis, Combinatorial Optimization, Theory of ODEs, Introduction to Systems Biology, Introduction to Number Theory, Variational Principles, Games Decisions and Behaviour, Introduction to Mathematical Statistics, Stochastic Processes.
- **From Physics:** Geophysics, Hamiltonian Mechanics, Climate Change, Computational Physics, Quantum Mechanics and its Applications, Electromagnetic Theory and Optics, Physics of Fluids, Stars, Experimental Particle Physics, Methods of Mathematical Physics.
- **From Computer Science:** Algorithms, Logic and Verification, Algorithmic Graph Theory.
- **From Economics:** Mathematical Economics 1A, Mathematical Economics 1B.
- **From Warwick Business School:** Foundations of Accounting, Foundations of Finance, Starting a Business, The Practice of Operational Research, Mathematical Programming II.
- **From Philosophy:** Logic II, History of Modern Philosophy.
- **Interdisciplinary Modules:** Applied Imagination, Challenges of Climate Change, The Science of Music.
- **Education Studies:** Introduction to Secondary School Teaching.
- **The Language Centre** at Warwick offers academic modules in Arabic, Chinese, French, German, Japanese, Russian and Spanish at a wide range of levels.

² The list of modules varies from year to year and is subject to changes in curriculum and staff research interests. This list is accurate for the 2016–2017 academic year.

Modules offered in 3rd year³

The 3rd year has no core

3rd Year Optional Modules from Mathematics and Statistics

- **Algebra and Discrete Mathematics**
Galois Theory, Rings and Modules, Groups and Representations, Commutative Algebra, Algebraic Number Theory, Set Theory, Combinatorics II.
- **Analysis**
Complex Analysis, Functional Analysis I, Functional Analysis II, Manifolds, Measure Theory, Markov Processes and Percolation Theory.
- **Geometry and Topology**
Fractal Geometry, Geometry of Curves and Surfaces, Introduction to Topology, Knot Theory, Algebraic Topology.
- **Real-World Systems and Applied Mathematics**
Topics in Mathematical
- **Probability and Statistics**
Bayesian Statistics and Decision Theory, Applied Stochastic Processes, Mathematical Finance, Designed Experiments, Probability Theory, Multivariate Statistics, Topics and Statistics, Medical Statistics, Topics in Data Science, Bayesian Forecasting and Intervention.
- **Other**
Problem Solving, History of Mathematics, Essay, Reading module.

Biology, Bifurcations
Catastrophes and Symmetry,
Introduction to Systems
Biology, Fluid Dynamics,
Numerical Analysis and PDEs,
Control Theory, Variational
Principles.

³ The list of modules varies from year to year and is subject to changes in curriculum and staff research interests. This list is accurate for the 2016–2017 academic year.

Other modules offered in 3rd year⁴

3rd Year Optional Modules from Other Subjects

- **Physics:** Statistical Physics, Weather and the Environment, Physics in Medicine, Quantum Physics of Atoms, Electrodynamics, Scientific Programming, Plasma Electrodynamics, Galaxies, Optoelectronics and Laser Physics, Cosmology, Nuclear Physics.
- **Computer Science:** Complexity of Algorithms, Computer Graphics, Compiler Design, Advanced Topics in Algorithms.
- **Engineering:** Modelling Systems and Control.
- **Warwick Business School:** Business Studies I, Operational Research and Strategic Planning, Business Studies II, Simulation, Mathematical Programming III, The Practice of Operational Research.
- **Philosophy:** Modal Logic.
- **The Language Centre** at Warwick offers academic modules in Arabic, Chinese, French, German, Japanese, Russian and Spanish at a wide range of levels.

⁴ The list of modules varies from year to year and is subject to changes in curriculum and staff research interests. This list is accurate for the 2016–2017 academic year.

Modules offered in 4th year⁵

4th Year Core Maths Module:

Research Project/Maths in Action Project.

4th Year Optional Modules from Mathematics and Statistics:

- **Algebra and Discrete Mathematics**
Presentations of Groups, Lie Groups, Representation Theory, Lie Algebras, Ring Theory, Graph Theory.
- **Analysis**
Fourier Analysis, Stochastic Analysis, Modular Forms, Asymptotic Methods, Calculus of Variations.
- **Geometry and Topology**
Algebraic Geometry, Differential Geometry, Riemann Surfaces, Geometric Group Theory, Cohomology and Poincare Duality.
- **Real-World Systems and Applied Mathematics**
Dynamical Systems, Advanced PDEs, Structures of Complex Systems, Large Deviation Theory, Population Dynamics, Introduction to Theoretical Neuroscience, Atmospheric Dynamics, Advanced Topics in Fluids, Topics in Complexity Science, Large-Scale Dynamics of Stochastic Particle Systems.
- **Probability and Statistics**
Dynamic Stochastic Control, Brownian Motion, Bayesian Forecasting and Intervention, Applied Stochastic Processes, Monte Carlo Methods, Topics in Applied Probability, Multivariate Statistics.
- **Theoretical Physics**
Relativistic Quantum Mechanics, High Performance Computing in Physics, Gauge Theories for Particle Physics, General Relativity, Quantum Mechanics Basic Principles and Probabilistic Methods, Statistical Mechanics.
- **Other**
Reading module.

Warwick tutors were happy to explain, great at motivating and effective at creating an environment where students wanted to learn.

Jason Davison,
MMath 2008-2012

SUPPORT FOR LEARNING

Tutorials

Your Personal Tutor is a member of academic staff. Tutors will advise on module choices, discuss mathematics with you in detail, help you to overcome minor and major problems, guide you through writing your 2nd-year essay, and write you reference letters.

Supervisions (1st and 2nd Year)

Your supervisor is a postgraduate or 4th year student. Being only a little older than you, your supervisor remembers the challenges of being a 1st year maths undergraduate and will support you through these challenges. The supervisor marks your homework providing feedback, and endeavours to answer your questions.

Small Analysis Classes

These help smooth the transition between school Calculus and undergraduate Analysis. Working in small groups, and supported by a

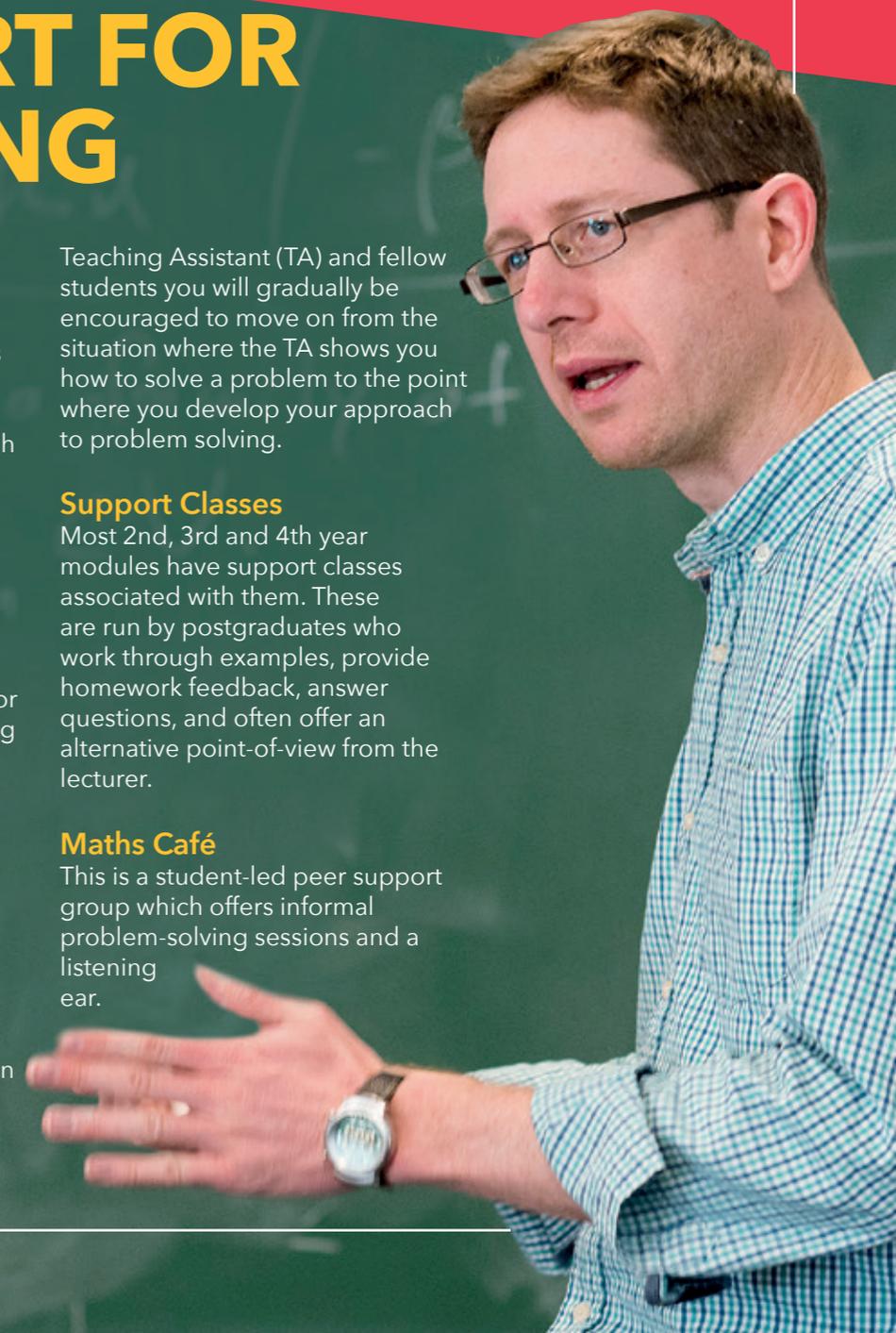
Teaching Assistant (TA) and fellow students you will gradually be encouraged to move on from the situation where the TA shows you how to solve a problem to the point where you develop your approach to problem solving.

Support Classes

Most 2nd, 3rd and 4th year modules have support classes associated with them. These are run by postgraduates who work through examples, provide homework feedback, answer questions, and often offer an alternative point-of-view from the lecturer.

Maths Café

This is a student-led peer support group which offers informal problem-solving sessions and a listening ear.



⁵ The list of modules varies from year to year and is subject to changes in curriculum and staff research interests. This list is accurate for the 2016–2017 academic year.

STUDY IN EUROPE

We encourage students to consider spending Year 3 at one of 23 European partner universities in Belgium, France, Germany, Italy, Malta, The Netherlands, Portugal, Spain and Switzerland.

If you're interested in this option, you can apply for it during your second year. Before you go we can prepare you with the necessary language skills through the Warwick Language Centre. After the year in Europe, you will return to Warwick for your final year. Your degree title will feature 'with Intercalated Year' or 'MMath with Study in Europe'.



"Spending a year in Germany has been a fantastic addition to my Warwick degree. Göttingen is a town that revolves around its student population, and one that has played an important role in mathematical history. Studying mathematics in another language is a unique experience. I learnt a new approach to several topics, meaning that at the end of the year I have not only come away with much improved German skills but also a much better understanding of the mathematics from my first two years. I made some lifelong friends from all over the world, with whom I spent a month travelling around Croatia and the rest of Germany. I am now considering working abroad in the future."

Natascha Mathews

spent a year in Göttingen (2014-15). She followed the G101 Maths with Intercalated Year Programme.



ADDED VALUE

(at the frontiers of knowledge)

Mathematics is constantly evolving. The Warwick Mathematics Institute is home to a number of world-leading research groups in pure and applied mathematics that keep our department at the forefront of research developments.

Active research areas include Algebraic Geometry, Number Theory, Probability, Geometric Analysis, Dynamical Systems, Mathematical Biology and Complexity Science.

Research initiatives involving mathematics at Warwick include:

- **Mathematical Interdisciplinary Research at Warwick**, fosters mathematical research and training across 11 academic disciplines.
- **The Centre for Scientific Computing**, driving high-performance computational research.
- **The Centre for Discrete Mathematics and its Applications**, brings together researchers in graph theory, combinatorics and operational research from Mathematics, Computer Science and the Business School.
- **The Warwick Mathematics Research Centre**. Founded in 1964, this was the first such centre in the UK. It runs many workshops and conferences, and hosts hundreds of visiting mathematicians every year from all over the world.
- **The Alan Turing Institute**. This is the national institute for data science, founded by the Mathematics, Statistics and Computer Science departments at Cambridge, Edinburgh, Oxford, UCL and Warwick.

"One of the best things about studying Mathematics at Warwick's Mathematics Institute is that you can be taught by and study under some of the most eminent and leading Mathematicians in their field. If you choose to do a third year essay or fourth year research project you have the incredible opportunity to be supervised by an expert in your area of interest."

Alexandra Embleton,

MMath 2011-2015

NTD CASE STUDY

Warwick's **Zeeman Institute** specialises in applying sophisticated mathematics to tackle challenges in biological sciences. It is named after Sir Christopher Zeeman, founder of the Warwick Mathematics Institute, and an enthusiast for using ideas from pure mathematics to approach problems in biology. Mathematicians from the Zeeman Institute teach several of our biology-oriented mathematics modules, and supervise the research projects of many of our maths undergraduates.



Neglected Tropical Diseases (NTDs) are some of the oldest and most painful diseases afflicting the world's poorest communities. The Zeeman Institute's work on NTDs, which is part-funded by the Bill and Melinda Gates Foundation, demonstrates the benefits of our Mathematics experts working alongside the School of Life Sciences. The teams' complementary skills and knowledge have helped make significant progress in understanding how these diseases are spread, and informing policy makers of how to contain them.

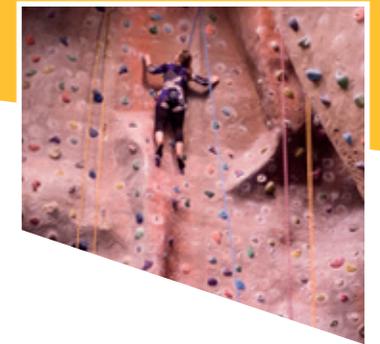
Deirdre Hollingsworth, Professor at the Warwick Mathematics Institute and the School of Life Sciences.

Deirdre uses mathematical models and statistical analysis to study the evolution and transmission dynamics of infectious diseases with the aim of informing the design of more effective control interventions.

"We're delighted to be part of the international effort to rid the world of these terrible diseases. We've made significant progress in understanding how they spread, measuring the impact of eradication efforts and highlighting areas where additional interventions will be required. We're optimistic that, with continued coordination and investment, we can protect more of the world's poorest communities from NTDs."



LIFE ON CAMPUS



Warwick Campus is like a miniature city, with restaurants, cafés, bars, shops, theatres and cinemas, set in beautiful parkland. Sporting facilities include a swimming pool, fitness complex, aerobics studio, weights room, climbing wall, athletics track, sports pitches and tennis courts, including an indoor tennis centre.

The recently renovated Students' Union, the hub of campus social life, caters for all tastes, with regular nightclub events and live bands. The Union runs 250+ societies and clubs from Accounting and Bridge to Drama (WUDS), Music Appreciation and Students in Free Enterprise (SIFE). There is also a very active undergraduate Mathematics Society (WMS) that organises weekly Maths Café drop-in help sessions and produces revision notes at exam time.

While at Warwick you could...

- Join a student society
- Do a short or summer work placement
- Join Warwick Volunteers and take on the role of Project Leader
- Teach schoolchildren in South Africa (Warwick in Africa)
- Do a summer research project
- Mentor young people through Warwick's Widening Participation Scheme.

"Make sure you get involved in things outside of study that you enjoy - sports clubs, societies etc. Employers always like students who are well-rounded as they fit in better in the office, and it makes the whole uni experience more fun and you get the most out of it."

Stuart Paton, Maths BSc with Intercalated Year 2008-2012

GLIMPSES OF MATHS RESEARCH AT WARWICK

You're perhaps curious about research-level mathematics that takes place at Warwick.

Here we present a few examples of theorems and ideas due to Warwick mathematicians. These have been chosen because their statements are accessible to A-level students, even though the methods and ideas behind some are very advanced. In perusing these, you'll notice that they're not motivated by practical applications. Some of the maths research at Warwick is aimed at solving real-world problems, but most of it is driven by a burning desire to know. You'll also notice that mathematicians in other countries are involved as collaborators, and this is typical: research is international.

These examples also give rise to further natural questions and new directions. Perhaps you might solve one of these some day?

Three Colourings of Maps

You might have heard of the Four Colour Theorem, proved in 1977 by Appel and Haken. A map is n -colourable if we can colour it using n colours so that no two adjacent regions share the same colour. The Four Colour Theorem simply says that any map is four colourable. You should be able (with a little experimentation) to draw a map that isn't 3-colourable.

A list R, S, T, U of four regions in a map is called a cycle of length 4 if R shares a border with S , and S shares a border with T , and T shares a border with U and U shares a border with R . You can define a cycle of length 5 in the analogous way. A famous problem in graph theory (from 1976) is known as Steinberg's conjecture. This claims that a map that doesn't have cycles of length 4 or 5 is 3-colourable. Many graph theorists have tried to prove Steinberg's conjecture.

In 2016 Steinberg's conjecture was disproved by Warwick graph theorists Daniel Kral and Michael Hebdige, working with colleagues in France and Chile. In fact they constructed a map with 123 regions that doesn't have cycles of length 4 or 5 and isn't 3-colourable.

Open problem: Is there a map that doesn't have cycles of length 4, 5 or 6 and isn't 3-colourable?

Irrationality of Odd Values of the Riemann-Zeta Function

We call a number rational if it can be written as a ratio of two whole numbers, and otherwise we say it is irrational. In your first week at university you'll probably see a proof that $\sqrt{2}$ is irrational. Another famous irrational number is π . For a whole number $n \geq 2$ we let:

$$\zeta(n) = 1 + \frac{1}{2^n} + \frac{1}{3^n} + \frac{1}{4^n} \dots$$

This is the Riemann-Zeta function, one of the most fascinating functions in mathematics, and intimately related to the distribution of primes. If n is even then $\zeta(n)$ can be written in terms of π or example:

$$\zeta(2) = \frac{\pi^2}{6}, \quad \zeta(4) = \frac{\pi^4}{90}, \quad \zeta(6) = \frac{\pi^6}{945}, \quad \dots$$

These expressions can be used to show that $\zeta(n)$ is irrational for even n . For odd n , it seems that $\zeta(n)$ is unrelated to π . For a long

time mathematicians have been trying to prove the irrationality of these odd values of the Riemann-Zeta function, with the only success being due to Roger Apéry who showed in 1978 that $\zeta(3)$ is irrational. Warwick mathematician Keith Ball, in collaboration with Tanguy Rivoal at Grenoble, showed that there are infinitely many irrational odd values of the Riemann-Zeta function.

Open problem: Is $\zeta(5)$ irrational?

Mathematical Art

Saul Schleimer is a Warwick geometric topologist. He has a particular talent for helping the public (and undergraduates) appreciate advanced ideas in geometry and topology through mathematical art and concrete models. As an example we mention here one of Saul's models, developed in collaboration with Henry Segerman at Oklahoma State University. A relatively common sight in graphic designs is of three gears in contact. However,

since neighbouring gears must rotate in opposite directions, none of the gears can move. Saul and Henry had the idea of designing a model of three interlocking gears that do actually move, and even printed a functional model using a 3D printer. You might want to google their article "Triple Gear" to see the mathematics that went behind the design or watch the YouTube video showing the gears in motion.



Sums of Cubes

The French mathematician Joseph Lagrange proved in 1770 that every positive whole number can be written as the sum of four squares of whole numbers.

Ever since, number theorists have been trying to prove similar theorems with squares replaced by higher powers. In the 19th century a huge experiment was carried out by hand where all numbers up to 12,000 were decomposed as sums of cubes

of non-negative whole numbers. On the basis of this experiment the German mathematician Carl Jacobi suggested in 1851 that every whole number bigger than 454 is the sum of seven cubes. This is now a theorem and many mathematicians have contributed towards the proof with the first steps being taken in the 1940s by Russian mathematician Linnik. But the final breakthrough that completed the proof came in 2016 and is due to Warwick

number theorist Samir Siksek; we now know indeed that every number bigger than 454 is the sum of seven cubes. Amazingly, besides ingenuity the last step did not require very advanced mathematics and the proof can be understood by a first-year undergraduate.

Open problem: Jacobi also thought that every number bigger than 8,042 is the sum of six cubes. Is he right?

A Module in Focus: Galois Theory.

A Module in Focus: Galois Theory. You might have wondered if there is a formula to solve a cubic equation, similar to the familiar quadratic formula. Such a formula was discovered by Niccolo Tartaglia (1500-1557) but is usually attributed to Gerolamo Cardano (1501-1576) who was the first to publish it.

To solve $ax^3+bx^3+cx+d=0$

$$\text{let } p = \frac{3ac-b^2}{3a^2} \quad \text{and} \quad q = \frac{2b^3-9abc+27a^2d}{27a^3}.$$

Then one of the solutions is given by

$$x = \sqrt[3]{\frac{-q}{2} + \sqrt{\frac{q^2}{4} + \frac{p^3}{27}}} + \sqrt[3]{\frac{-q}{2} - \sqrt{\frac{q^2}{4} + \frac{p^3}{27}}}$$

with the other two solutions given by similar expressions. Shortly afterwards Lodovico Ferrari (1522-1565) gave a formula for the solving quartic (i.e. degree 4) equations. For the next 250 years mathematicians searched in vain for a formula for solving quintic equations. Evariste Galois (1811-1832) finally showed that there is no such formula (shortly before getting himself killed in a duel). Galois studied the symmetries of the solutions, and realised that when the degree is at least 5 the symmetries are too complicated for there to be a formula. In the third year Galois Theory module these symmetries are studied and measured using the modern language of groups and fields.

The language is so powerful that along the way many seemingly hopeless questions are resolved. For example, you probably remember how to bisect an angle using a ruler and compass. In this module it is shown by dimension counting that angles can't be trisected using a ruler and compass.

LIVING AT WARWICK

Accommodation

On or Off Campus?

- Students joining the University for the first year are given priority for a room on campus. See Frequently Asked Questions on the Accommodation website, warwick.ac.uk/accommodation
- Second and most final-year students live off-campus, many in group houses in nearby Earlsdon, Kenilworth and Leamington.

Campus Rooms

- Over 6,400 rooms of all types: en-suite single or shared rooms; study bedrooms; flats for small groups.
- A choice of 34-week or 39-week lets, the latter allowing you to stay for the two shorter vacations.
- Prices ranging from £72 to £157 per week in 2017-18.

Off-Campus Accommodation

Most students rent from Warwick Accommodation:

- It has hundreds of properties in Coventry, Kenilworth and Leamington Spa.
- They are well maintained and furnished. There are no hidden costs.
- They are close to convenient bus routes to the University.

For more details see warwick.ac.uk/accommodation

Leamington Spa:

- Is a centre of the computer games industry
- Has an elegant Georgian town centre
- Has a sizable student population



YOUR FUTURE STARTS HERE

As a Warwick graduate with a mathematics degree, you will have excellent prospects for a wide range of careers, the most popular areas being the Financial Sector (Accountancy, Actuarial and Investment Banking), Computing and Education.

Recent graduate job titles have included: Actuary, Business Intelligence Consultant, Chief Analytics Officer, Computer Games Designer, Consultant Software Engineer, Financial Consultant and Adviser, Financial Software Developer, Investment Banking Analyst, Market Risk Manager, and Mathematics Teacher.

Our Careers Service works for you, providing skills training, careers advice and information, and will continue to support you for up to three years after your graduation. See warwick.ac.uk/careersandskills

Why is a Warwick Maths Degree an Excellent Career Move?

In today's workplace, the ability to adapt to change and to learn new things is as important as having a particular range of knowledge.

During a Warwick Mathematics degree you will develop many of the qualities of intellect and temperament needed to meet new challenges, including:

- Analytical Skills
- Logical Thought-Processes
- Problem-Solving Ability
- Investigative Skills
- Communication Skills
- Effective Working Habits



"My degree has set me up to either continue with research or pursue an interesting and lucrative professional career. The Warwick Maths course has a deservedly high reputation and I got interviews with very selective international companies based on it."

Samuel Watts,
MMath 2008-2012

ALUMNI EXPERIENCES



Lorna Flint,
Maths BSc 2010-2013

Now Business Intelligence Developer, Civica Digital

In my second year at Warwick I did a lot of research into the spread of tuberculosis in cattle. In completing that, I looked at an enormous amount of data. Luckily for my sanity, it transpired that data was very much my thing. This definitely drove my career choice.

Business intelligence is really varied, but essentially is helping companies and organisations make best use of their data. In my third year of university I received an email to all the Maths students from a company called Thorogood about applying for a business intelligence graduate role. As I was interested in data I went along to an interview, and then assessment centre. They showed me how data reporting in



Stuart Paton,
Maths BSc with Intercolated Year 2008-2012

Now Investment Actuary, Just

I'm currently working in London as an Investment Actuary at Just, a life insurance company. In my team we are responsible for the investment strategy of the company - selecting the right assets for the company to invest in to back the policies that are sold by the company. I've worked at my current company for just over 18 months. Prior to this I spent 2 years at an actuarial consultancy.

After university, I took a year off to spend time travelling and just enjoy exploring - I didn't want to stress myself

SSRS and Excel could be used to drive business decision making. I found this really interesting. I looked for a role in a company which was a Microsoft BI gold partner near Bristol. A couple of weeks before graduation I received my first job offer from IPL in Bath.

I'm personally motivated by responsibility and variety. It's a great feeling when you are able to put your heart and soul into all aspects of a project and it be a success - I want to be good at what I do. And I can't mention motivation without a small nod to money-my earnings in my role give me the freedom to enjoy my time outside the office.

out trying to apply for jobs whilst sitting final-year exams, and it gave me time to really think about what I wanted to do and explore my options. I wanted a job where I could use my maths skills (perhaps not specifically the content, but more the analytical background) and apply this to something tangible, whilst working with like-minded people. The actuarial profession is an area that a lot of my friends had already gone into. It provides a decent qualification (and a few structured years of study while doing this), and is well paid.



Rachel Player,
MMath 2009-2013

Now PhD student. Information Security Group at Royal Holloway, specialising in lattice-based cryptography.

Learning more maths had been my goal for as long as I could remember, so it was only natural to study Mathematics at degree level. As it turned out, Warwick was a great place to develop this interest. The MMath course gave me the opportunity to study a wide range of modules (not only in maths but also, for example, in physics). During my first two years I discovered that my interest was in number theory and algebra, and I was able to study many advanced modules in these areas throughout my degree. During my final year I was fortunate to work with Prof. Samir Siksek, who supervised my MMath research project in number theory. Samir was extremely enthusiastic and helpful, and I enjoyed this project so much I began to think seriously about a career in research. At the same time, a sense of pragmatism kicked in, and I was wondering how best to use all this maths I was excited about. Then it dawned on me: I should try the canonical application of number theory, cryptography!

My role as a PhD student involves conducting research and writing papers. I regularly have the opportunity to present my work at seminars and conferences, both in the UK and abroad. I have recently completed a 3 month internship in the Cryptography group at Microsoft Research, Redmond, USA, and presented some joint work arising from the internship at a workshop in Malta.

Maths Quiz

For her MMath Research Project Rachel investigated factorials that can be written as sums of three Fibonacci numbers, for example $6! = F_8 + F_{11} + F_{15}$

Rachel found all such examples, and proved that there aren't any others.

How many can you find?

FEES AND WIDENING ACCESS

Academic Fees

- At the time of publication (06/17) Home/EU fee levels for 2018-19 entry were not yet agreed. Our fees, once confirmed, will be published online at

www.warwick.ac.uk/services/academicoffice/finance/fees

- Academic fees for Overseas full-time undergraduate students in 2018-19 are expected to be £23,380 per year.

The fees cover tuition, examination registration and some student amenities, but not accommodation, meals or other personal items. Fees for subsequent years will depend on government decisions.

For further details about fees for home/EU and Overseas students, see

warwick.ac.uk/ugfees

Removing Barriers

Some financial support for home students from families on modest incomes will be provided through Warwick National Scholarships and Warwick Bursaries.

More information can be found at

warwick.ac.uk/services/academicoffice/funding

VISIT US

Undergraduate Open Days

The University organises four undergraduate open days in early summer and in autumn for students wishing to visit the University. Students and their accompanying guests are offered a guided tour and can visit the academic departments of their choice. Book early to avoid disappointment.

For more details, see warwick.ac.uk/opendays

Maths Offer Holder Days

If you receive an offer from us, you will be invited to one of our Maths Offer Holder Days between January and March 2018.

A visit to the Mathematics Institute will give you a good idea of the atmosphere of the University and the style of the mathematics we teach.

Our Offer Holder Days are informal and there are no interviews. They give you an opportunity to meet members of staff, to ask questions about courses and campus life, and to talk to students who are already here.

How to apply

Applications are made through UCAS: www.ucas.com. If you accept our offer and get the required grades in your exams we will confirm your place and look forward to warmly welcoming you at the start of your life here at Warwick.

www.warwick.ac.uk/study/undergraduate/apply

Applicants living outside the UK

Warwick welcomes applications from international students. Local advice about the application procedure is available from all British Council offices and Warwick representatives.

www.warwick.ac.uk/study/international

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