Department of Mathematics
Undergraduate Studies
Royal Holloway is one of the UK’s leading research intensive universities. One of the larger colleges of the University of London, we are strong across the sciences, social sciences, arts and humanities. We were ranked 19th in the UK (129th in the world) by the Times Higher Education World University Rankings 2015-16, which described us as ‘truly world class’.

As an international community, with students from 130 countries, we focus on the support and development of the individual. Our friendly and safe campus, in Surrey, 40 minutes by train from central London, provides a unique environment for university study where students quickly feel at home.

“One of the 16 most beautiful universities in the world” (Daily Telegraph).

Visit us

Our College and departmental Open Days offer you a unique opportunity to come and find out more about us and get a taste of what university life is really like. Parents and friends are very welcome to come with you. To find out dates and register to attend please visit our website: royalholloway.ac.uk/opendays
Welcome to Mathematics

Mathematics is one of the oldest academic disciplines, yet today it is thriving as never before. Many areas of modern life are based on, and indeed would not exist without, mathematical ideas, from mobile phones, the internet and satellite navigation to financial markets, weather forecasts, insurance, drug testing, and X-rays. In addition, many situations require logical and analytical thinking – a skill you develop by studying mathematics. For these reasons, we find that our graduates are highly employable.

Mathematics is not only widely applicable, it is also beautiful. Simply doing mathematics can be deeply satisfying; finding the solution of a difficult mathematical problem is uniquely thrilling and requires a high level of creativity. If you enjoy mathematics and are looking forward to studying at a leading UK department we hope that you will apply to join us here.

Professor James McKee
Head of Mathematics

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Why study Mathematics?

Mathematics is intrinsically beautiful and can be studied for its own sake: you can gain pleasure from the subtleties of sets, numbers, patterns and algebraic structures, and develop logical and analytical skills.

Mathematics is also the central tool in the physical and natural sciences as well as in other disciplines such as finance, economics, management and IT. By studying Mathematics you gain a diverse range of transferable skills. You learn how to apply the universal language of mathematics in a multiplicity of situations and see connections between them.

Mathematics also provides an excellent foundation for a variety of fulfilling career paths or opportunities for further study.

Mathematics at Royal Holloway

The Department of Mathematics is a lively and friendly place with an international reputation for the quality of its teaching and research. Academic staff are active in pioneering research which is making an impressive impact on the world stage, in Pure Mathematics, Information Security, Statistics and Theoretical Physics. This strong research culture influences our curriculum, helping students to keep in touch with the latest developments in the field. Whatever your taste in Mathematics, Royal Holloway’s varied curriculum will have something to suit you.

LEADING RESEARCH
The Research Excellence Framework (REF 2014) confirmed that the Department of Mathematics is one of the best in the UK, ranked second for research impact, and fourth for the proportion of research output classified as world leading or internationally excellent. Our staff’s passion and enthusiasm for the subject transmits through their teaching.

A SUPPORTIVE LEARNING ENVIRONMENT
The academic experience is consistently highly ranked by our students in the National Student Survey. We place an emphasis on small-group teaching, creating a friendly and motivating atmosphere where you’ll be known as an individual. Our academic staff support problem solving sessions, small group tutorials and workshops. Staff are always ready to give help and advice, and our personal adviser system will guide you through your studies.

FLEXIBLE AND CHALLENGING COURSES
We offer a wide range of flexible degree programmes, which enable you to mix Mathematics with other subjects and explore your broader interests. Our courses are challenging and cover a varied curriculum, including pure mathematics, discrete mathematics, statistics, cryptography, quantum mechanics, informatics, and financial mathematics.

EXCELLENT CAREER OPPORTUNITIES
Study Mathematics with us and open up a wealth of opportunities. We have a competitive placement scheme open to all our second year students to gain valuable work experience. 90 per cent of our graduates go on to work or further study within six months of graduating (Unistats, 2014).

THRIVING POSTGRADUATE COMMUNITY
We offer an extensive array of postgraduate opportunities within our thriving research portfolio, including, as part of our School of Mathematics and Information Security, the internationally-renowned Information Security Group.

“Mathematics is the door and the key to the sciences... for the things of this world cannot be made known without a knowledge of Mathematics.”
Philosopher
Roger Bacon (c. 1260)
Mathematics is a subject that can be studied on its own, or fruitfully combined with a large variety of other academic subjects. It is sometimes difficult to know which combination to choose, and we provide as much flexibility as we can in the early stages of our programmes. If you would like further advice about any particular option, then do please contact our Admissions Tutor.

**Degree programmes**

<table>
<thead>
<tr>
<th>Single Honours</th>
<th>Joint Degrees (50%)</th>
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<tbody>
<tr>
<td>G103 Mathematics MSci (four-year)</td>
<td>GG41 Computer Science &amp; Mathematics</td>
</tr>
<tr>
<td>G100 Mathematics BSc (three-year)</td>
<td>LG11 Economics &amp; Mathematics</td>
</tr>
<tr>
<td>G150 Mathematical Studies BSc</td>
<td>NG31 Finance &amp; Mathematics</td>
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</tbody>
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| Specialist Degree | | |
|-------------------|----------------|
| G1G3 Mathematics with Statistics | GN12 Mathematics & Management |
| | GW13 Mathematics & Music |

| Mathematics as a Major Subject (75%) | | |
|--------------------------------------|----------------|
| G1R1 Mathematics with French | GFC3 Mathematics & Physics MSci (four-year) |
| G1R2 Mathematics with German | GF13 Mathematics & Physics BSc (three-year) |
| G1R3 Mathematics with Italian | |
| G1N2 Mathematics with Management | |
| G1V3 Mathematics with Philosophy | |
| G1R4 Mathematics with Spanish | |

| Mathematics as a Minor Subject (25%) | |
|--------------------------------------| |
| R1G1 French with Mathematics | |
| R2G1 Management with Mathematics | |

For degree programme outlines please see page 7.

**Admissions and entry requirements**

The department admits about 150 new students each year. We welcome applicants from a diverse range of backgrounds on the basis of attainment at A-level or equivalent qualifications.

Prospective students are encouraged to visit the department, talk to members of staff and students and find out more about studying at Royal Holloway on one of our open days. Parents are welcome to visit the department at the same time. We also invite many applicants for an informal interview when possible.

**TYPICAL OFFERS**

For Mathematics degrees we are looking for students with an A in A-level in Mathematics. Although two Mathematics A-levels are a help, especially in the first year, we do not assume that our students will have more than one and so the starting point of our first year courses is based on the A-level ‘common core’.

For degree courses combined with other subjects, the conditions may vary slightly: see our departmental website for full details and entry requirements.

We accept many alternatives to traditional A-levels, so long as the qualifications are sufficiently rigorous and cover the core material needed to begin a degree in Mathematics. Mature students are encouraged to apply.

We assess each applicant individually, taking into account personal circumstances. If you have any queries, please contact the Departmental Admissions Tutor.

**DEFERRED ENTRY**

Applications from candidates who wish to take a year’s break between school and university are accepted.

Royal Holloway has a comprehensive admissions policy which sets out how your application will be dealt with. For further information visit: royalholloway.ac.uk/admissionspolicy
We offer a BSc in Mathematics with Statistics, enabling students to concentrate on the theory and applications of statistics. Alternatively, students can choose from a variety of degree programmes that are shared between Mathematics and another subject: the large number of available combinations provides the opportunity for you to pursue your other interests. We also offer a flexible Mathematical Studies BSc that is rooted in mathematics but allows other academic interests to be pursued alongside the mathematical heart of the programme.

All undergraduate degree programmes at Royal Holloway are based on the course unit system. This system provides an effective and flexible approach to study, while ensuring that our degrees have a coherent and developmental structure. This is particularly essential in Mathematics, which is both logical and wide-ranging. In the case of some of our combined degree programmes, it also makes it possible to change the balance of your subjects during your time at Royal Holloway.

Please check our website for detailed lists of the units taken for each different degree programme.

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### Degree structure

At the centre of our teaching programme are two specialist degrees: the MSci in Mathematics (a four-year degree, called an MMath in some universities), and the BSc in Mathematics (a three-year degree). We offer a BSc in Mathematics with Statistics, enabling students to concentrate on the theory and applications of statistics. Alternatively, students can choose from a variety of degree programmes that are shared between Mathematics and another subject: the large number of available combinations provides the opportunity for you to pursue your other interests. We also offer a flexible Mathematical Studies BSc that is rooted in mathematics but allows other academic interests to be pursued alongside the mathematical heart of the programme.

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### Year 1 (G100/G103)

- Calculus
- Functions of Several Variables
- Number Systems
- Matrix Algebra
- Numbers and Functions
- From Euclid to Mandelbrot
- Introduction to Applied Mathematics
- Principles of Statistics

### Year 2 (G100/G103)

- Linear Algebra and a Group Project (the project may be in any area of Mathematics)
- Real Analysis
- Complex Variable
- Plus five from:
  - Vector Analysis and Fluids
  - Ordinary Differential Equations and Fourier Analysis
  - Statistical Methods
  - Probability
  - Groups and Group Actions, or Further Linear Algebra and Modules
  - Graphs and Optimisation

*Given in alternate years.

### Year 3 (G100/G103)

- Mathematics in the Classroom
- Number Theory
- Groups and Group Actions, or Further Linear Algebra and Modules
- Quantum Theory I
- Dynamics of Real Fluids
- Electromagnetism
- Non-Linear Dynamical Systems
- Quantum Information and Coding, or Quantum Theory II
- Inference
- Time Series Analysis
- Applied Probability
- Mathematics of Financial Markets
- Advanced Financial Mathematics
- Error-Correcting Codes
- Cipher Systems
- Principles of Algorithm Design, or Complexity Theory
- Channels
- Combinatorics
- Computational Number Theory
- Public Key Cryptography
- Applications of Field Theory
- Topology
- A Supervised Project

The precise selection of courses is liable to vary from year to year, but the above gives some indication of the available range.

*Given in alternate years.

### Year 4 (G103)

- A Supervised Project
- Plus six from:
  - Computational Number Theory
  - Applications of Field Theory
  - Combinatorics
  - Quantum Information and Coding, or Quantum Theory II
  - Advanced Financial Mathematics
  - Principles of Algorithm Design, or Complexity Theory
  - Channels
  - Public Key Cryptography
  - Advanced Cipher Systems
  - Theory of Error-Correcting Codes

It is possible to include one or two from the Year 3 list.

*Given in alternate years.
Degree programme outlines

Mathematics is unique – at the same time it is both a beautiful and fascinating world of abstract structures and ideas and a practical subject at the heart of modern science and technology. We offer a broad range of degree programmes so that you can select a course to suit your interests.

G100 MATHEMATICS BSC (THREE-YEAR)
G103 MATHEMATICS MSCI (FOUR-YEAR)
The MSci degree is primarily aimed at students who will continue to use mathematics at a high level after graduation – for example in industry or research – while the BSc is aimed at students who will use mathematical skills in areas such as management, accountancy and teaching. The programmes have a common first year, and the choice between them is made at the start of the second year, so it does not matter which degree you register for initially.

G150 MATHEMATICAL STUDIES
Mathematical Studies provides the flexibility to pursue options outside of mathematics, with up to one quarter of the courses being taught by other departments. There are five compulsory Mathematics modules in the first year: Calculus, Function of Several Variables, Number Systems, Matrix Algebra, and Principles of Statistics. Other subjects taught span Computer Science, Philosophy, Sociology, Physics or Management. The second and third years provide flexibility to choose various combinations with the possibility of transfer to BSc Mathematics after one year.

G1G3 MATHEMATICS WITH STATISTICS
Statistics is based on Mathematics, not only because the data used are usually numerical, but because the fundamental concepts of probability theory are closely linked to pure mathematics. Therefore, there is a demand for graduates with a good understanding of Mathematics who can use statistical methods correctly, and this course aims to produce such graduates.

G1N2 MATHEMATICS WITH MANAGEMENT
All business organisations face problems which are basically quantitative, and managers must make decisions on, for example, the allocation or acquisition of resources. Managers often lack the mathematical background to understand these techniques, while the consultants used may not understand the background to the problems. The degree course provides graduates with an understanding of business, as well as a thorough grasp of the appropriate branches of Mathematics.

G1V5 MATHEMATICS WITH PHILOSOPHY
Philosophy addresses fundamental questions about knowledge, reasoning, our view of the universe, and their impact on people’s lives. Greek philosophers introduced the idea of applying Mathematics to describing the universe. The philosophy courses in this programme include Greek and Roman Philosophy, Modern European Philosophy, and the Philosophy of Politics.

G1R1 MATHEMATICS WITH FRENCH;
G1R2 MATHEMATICS WITH GERMAN;
G1R3 MATHEMATICS WITH ITALIAN;
G1R4 MATHEMATICS WITH SPANISH
Galileo described the universe as a book written in the mathematical language, and the concept of Mathematics as a universal language is a powerful one. Like other languages, it can be studied for its own sake, and also as a vehicle for transmitting ideas, so it is logical to study Mathematics with a foreign language. Note that these are three-year degrees and do not include a year abroad.

GG41 COMPUTER SCIENCE & MATHEMATICS
There is an obvious connection between Computer Science and Mathematics – many of the subjects studied by computer scientists are basically mathematical, and there is no branch of Mathematics which has not been radically altered by computer techniques. This combination opens up a very wide range of career opportunities.

LG1T ECONOMICS & MATHEMATICS
In areas of management consulting and in financial institutions, advanced mathematics and computing are vital in determining the best strategy for the firm and for investing in different assets. The Economics courses consider the analysis of individual behaviour and markets, with options in financial and industrial economics and other fields; econometric analysis shows how to analyse data. The Mathematics courses consider the fundamental properties of the Mathematics used, from calculus to probability and statistics, graphs and optimization and financial mathematics.

NG31 FINANCE & MATHEMATICS
Just as physical quantities such as distance and time are described numerically, and the laws of physics use mathematics, money is quantitative, and the study of finance needs a good knowledge of mathematics. This programme provides the mathematical skills and the economic background needed, and gives insight into ideas such as risk and return, volatility and the sophisticated mechanisms observed in financial markets. Graduates will be well placed to find jobs in the City, in banking and in financial consultancy.

GN12 MATHEMATICS & MANAGEMENT
Managers in any business are faced with varied and usually complex situations. There are always issues of finance, logistics, inventory control, scheduling and so on – and the skills developed in a Mathematics degree are just the ones needed. Combine these with a study of Management and Accounting, and you will be well equipped when you graduate.

GW13 MATHEMATICS & MUSIC
Both Mathematics and Music are concerned with the creation, understanding and analysis of abstract patterns. In the 6th-century BC Pythagoras and his followers developed a unified theory of arithmetic, geometry and music, based on ideas of proportion and harmony. This was the μόδημα, or ‘what should be learnt’, from which the name Mathematics comes.

GC43 MATHEMATICS & PHYSICS MSCI
(FOUR-YEAR)
GF13 MATHEMATICS & PHYSICS BSC
(THREE-YEAR)
Mathematics and Physics have formed a fruitful partnership for centuries, enabling us to explain and predict the behaviour of the universe. The compulsory core of the course contains the fundamental ideas of Physics, the useful ideas and techniques of Mathematics, and the wide range of options available allows you to follow your own interests.

The MSci degree is aimed at those who wish to develop and an advanced understanding of how mathematics can describe and predict the physical universe and who will continue to use mathematics and physics at a high level after graduation, such as in research or industry. The MSci and BSc programmes have a common first year, and the choice between them is made at the start of the second year, so it does not matter which degree you register for initially.
Teaching and assessment

Mathematics at Royal Holloway is not just about collecting skills and information for a future career (though of course that is important). It is about developing a feel for the subject in many different, often small, ways, and becoming part of a community of people who care about the subject.

A variety of teaching methods are used. Generally the first year courses are taught by a combination of lectures, problem-solving workshops and tutorials in groups of four or five; in the second year we use lectures and workshops; and in the third and fourth years mostly lectures.

As Mathematics is only learnt by practice, we support every course with weekly worksheets: the students’ work is collected, corrected where necessary, and returned with comments. This feedback is a vital part of the teaching and learning process.

Computers are used as an aid in many courses, especially in statistics. Simple use of a powerful mathematical computing package is taught to all students; it can be used in a variety of ways, for instance to check any routine calculation (numerical or algebraic).

Learning to prepare and present the results of your work is something we (and employers) see as important. In the second year, all students work in small groups to prepare a report and an oral presentation on a mathematical topic of their choice. Most of the statistics courses include a project component, and in the third year, two courses (Mathematics in the Classroom and one Mathematics Project course) are assessed entirely by project work. A supervised project forms a quarter of the work in the final year of the MSci. In a typical week, students will attend 12–15 hours of formal teaching: lectures, tutorials, workshops and computer classes. Outside of these times, students are expected to work on worksheets, revision, and preparation of projects. Apart from projects all courses are examined by written papers in the Summer Term.

There is more to learn in a Mathematics course than the material presented in lectures. You must be able to convince yourself of the validity of a piece of Mathematics and to present results to others in an intelligible fashion – to explain something you have just learnt (or, even better, just discovered) can be a pleasure.

Our research interests, such as number theory, cryptography, quantum dynamics and information theory, influence our curriculum, particularly in the final year. These subject areas are extremely useful – they give students the tools to apply their Mathematics in real-life situations.
The department

The Department of Mathematics is housed in the McCrea Building, named after the remarkable Professor William McCrea, FRS, former Head of Mathematics and one of the leading cosmologists and relativists of his generation.

We have a dedicated computer laboratory for students, and a range of specialist Mathematics software available. Further computer facilities (some with 24-hour access) are conveniently located around the campus. Data Cabling and wireless networks in residences provide you with intranet access to use your computer laptop for your studies.

The Bedford Library holds an extensive stock of Mathematics textbooks, monographs and journals, and is next to the McCrea Building.

Our compact size helps to promote a friendly and inspiring atmosphere where students are known as individuals. Staff are always ready to give help and advice, and a member of staff is also assigned to you as a Personal Adviser. Your Personal Adviser will help you with any queries or difficulties and guide you in your choice of courses. Typically, your Adviser will be the person who writes your job references in the final year.

Royal Holloway has a vibrant social scene and a friendly campus environment.

Mathsoc is a social society run by students to bring maths and non-maths students together through a mixture of social and academic events, ranging from pub quizzes and trips to guest lectures and career talks.

Our location in a beautiful part of Surrey on the edge of Windsor Great Park has excellent national and international communication links (around 40 minutes by train to London Waterloo, and seven miles from Heathrow).

POSTGRADUATE OPPORTUNITIES

A Mathematics first degree is a useful platform from which to go on to further study, and the department offers exciting postgraduate opportunities. Our MSc degrees equip you for more specialised types of employment by studying Mathematics for Applications or Mathematics of Cryptography and Communications.

We have earned an international reputation for our research, reflected in our strong performance in recruiting PhD students and post-doctoral researchers and in attracting research grants in a diverse range of areas, including Number Theory, Cryptography, Quantum Dynamics and Information Security. The department forms one half of the School of Mathematics and Information Security; the other half is the internationally renowned Information Security Group (ISG). The ISG offers a Masters in Information Security with a year in industry option and is home to the EPSRC Centre for Doctoral Training (CDT) in Cybersecurity for highly trained researchers. Through our research, we aim to extend the boundaries of the subject and make a difference in the real world.

MATHEMATICS IN THE CLASSROOM

Endorsed by the DTI and DfES, the Undergraduate Ambassadors Scheme provides an opportunity for third year undergraduates to gain valuable transferable skills and experience of science education. Each student spends half a day each week, for one term, in a local school. You will work under the supervision of a specific teacher, who will act as a trainer and mentor, and determine your tasks and responsibilities. This course counts towards the final degree result in the same way as other third year Mathematics courses. For more information, visit: www.uas.ac.uk

STUDENT VIEW

“Our Mathematics department building McCrea, that is reminiscent of a Lego construction, houses the offices of our friendly lecturers and support staff. They, along with my lovely classmates and friends, made studying the difficult but interesting subject of Mathematics and coping with all the highs and lows during the three years at Royal Holloway, a smoother journey.

The office hour system is one to take advantage of – if you tried your best and still need help, just go ask for it!”

Sharon Wan, BSc Mathematics with Management
Your future career

A degree in Mathematics from Royal Holloway can lead onto many different career paths and we take the employability of our graduates very seriously. The strong links which the department has with various companies and organisations helps us to stay in touch with the very latest needs of employers. University of London degrees enjoy international recognition, and are especially valued by employers.

GRADUATE DESTINATIONS
Our graduates have gone on to careers in a range of jobs including:
- IT Consultants and Planners
- Computer Analysts and Programmers
- Computer Operations Managers
- Chartered and Certified Accountants
- Teachers
- Actuaries

Graduates are working for well-known organisations such as:
- KPMG
- Ernst & Young
- Ministry of Defence
- Lloyds Banking Group
- Logica
- McLaren
- TowersWatson

CAREERS SUPPORT AND INTERNSHIPS
The department endeavours to help students to recognise their own strengths, skills and abilities so that they can make strong applications for their chosen job or training course. Advice on careers – including completing application forms and preparing for an interview – is provided by the College Careers Service, which is part of the University of London Careers Advisory Service.

The careers team also hold regular sessions, specifically for Mathematics students, on summer internships, vacation employment and the careers available to them on graduation.

The department has a range of placement schemes designed to enhance employability and to give a taste of the workplace. Our flagship scheme is a competitive placement scheme open to all second year students. As part of the scheme all of our students go through a basic training process on how to apply to placements and jobs: they attend a CV writing workshop and receive professional comments on their CV.

Every student in the department has a personal adviser who guides them through their time at Royal Holloway, and who will become a natural choice for writing references for job applications.

For further information on careers and employability, visit royalholloway.ac.uk/mathematics/yourfuturecareer

MATHS CAREERS WEBSITE
The Institute of Mathematics and its Applications, together with the London Mathematical Society and the Royal Statistical Society, have recently launched a new Maths Careers website. This site includes useful advice on finding the right career. For more information, visit: www.mathscareers.org.uk
Alumnus: Kavit Khagram  
Subject: BSc Mathematics  
Graduated: 2009  
Place of Work: Guy Carpenter Analytics  
Position: Vice President  

“My job is statistics heavy and the courses studied during my UG and PG helped immensely in giving me the firm grounding that some graduates seem to lack. Brokers are required to have in depth market knowledge and an understanding of the behaviour of our clients and the reinsurers that we work with. Studying game theory helps assess most situations faced in the workplace from an analytical stand point. My advice is to think carefully about the career path you wish to pursue after university and choose the most appropriate courses for that path.”

Alumna: Katie Lawrence  
Subject: BSc Mathematics  
Graduated: 2009  
Place of Work: McLaren  
Position: Race Operations Engineer  

“My degree certainly helped me progress onto my Masters, as academically it is a very well respected university. This was also noted upon my entry onto the graduate scheme at McLaren where I moved onto supporting customer teams both in Formula 1 and GT, development of the GT car model for simulation use, track aerodynamic and traction control support and as a race strategist, developing modelling of overtaking and working directly with the drivers on the influence of reaction tests on launch performance. The support I gained at Royal Holloway was also amazing, supporting me through my Masters application and also for a PhD I applied for and support with my CV.”

Alumna: Dr Helen Warren  
Subject: BSc Mathematics with Statistics  
Graduated: 2007  
Place of Work: London School of Hygiene & Tropical Medicine (LSHTM)  
Position: Research Fellow in Statistical Genetics & Epidemiology  

“In the summer after my second year, I participated in the University of London’s City Course, which our Careers Service had advertised. This actually helped to confirm that a job in the financial sector wasn’t for me! Then after especially enjoying the statistics courses and seeing interesting applications to medical statistics, I plucked up the courage to say to my lecturer “This is what I want to do!” to which the response was, “Let’s chat over coffee” and before I knew it, I was being given the encouragement and support to challenge myself and apply for a PhD, as many such careers, whether in research or pharmaceutical industries, for example, prefer postgraduate experience.