WHTC University application subject guides

Mathematics

This guide has been written to help support you in your application to university. It contains the following information relevant to your subject to help you decide where to apply and put together the best application that you possibly can:

1. Course Links

Kinds of Mathematical Course

Universities can offer many different types of Mathematics Courses. This should be the first choice you make when choosing a degree. Below is an outline of common courses with the mathematical sciences:

1. BSc Mathematics

- Typically, a three-year course, which gives you the opportunity to study a wide range of mathematical topics. Will prepare you for many graduate jobs and possible further studying including the PGCE and many MSc courses.

2. MMath Mathematics

- A four-year master's level degree course, it offers a good basis for a wide range of employment, including a career as a professional mathematician or statistician in industry or research in the higher education sector. A third of your final year will be spent studying a topic in depth and producing a master's thesis.

- It is often easier with student finance to apply for an MMath degree and then drop down to a BSc, rather than apply for a BSc and move up to MMath. MMath courses will sometimes have higher entry requirements though.

3. BSc (or MMath) Mathematics and Statistics

- A maths and statistics degree will train you to spot and understand patterns in this data, and to make careful predictions about the future. From marketing strategies to psychology, from engineering to medicine, statistics is necessary to understand the world around us.

4. **BSc (or MMath) Mathematics with a Year Abroad**
    - The first two years of the course are identical to a single honours' mathematics degree, providing a broad background in pure, applied, and statistical mathematics which underpins more advanced material later. You will spend your third year abroad at a partner university. There will normally be a final year at your original university to complete your degree.

5. **BSc (or MMath) Mathematics with a Year in Industry**
    - The first two years of the course are identical to a single honours' mathematics degree, providing a broad background in pure, applied, and statistical mathematics which underpins more advanced material later. Your third year will be an invaluable opportunity to apply your theoretical thinking in a real-world workplace. There will normally be a final year at your original university to complete your degree.

Top Courses

Below are links to some of the top courses for Mathematics in the UK (according to The Complete University Guide). The number next to them shows their ranking. Click on the links to find information about what the course is like, what you'll learn, and loads of information about things such as fees and accommodation. However, remember that there are loads of other great universities out there, so check out The Complete University Guide or just google studying your subject at university.

1. University of Oxford
2. University of Cambridge
3. University of St Andrews
6. University of Warwick

8. UCL

16. University of Nottingham

2. Recommended A-Levels, Entrance Exams and Entry Requirements

2.1 Recommended A-Levels

It is entirely recommended to take both A-Level Mathematics and Further Mathematics to study mathematics at university. Some universities, however, will still accept you with a suitable score in an admissions test.

To go alongside Mathematics and Further Mathematics, a scientific or mathematical subject is the most natural choice (Physics, Biology, Chemistry, Economics). Choosing one of these however is by no means necessary, and any other subject can be partnered with Mathematics and Further Mathematics.

2.2 Entrance Exams

Top universities either require an admissions test for their mathematics courses or will use a test score to reduce the A-level requirement for such courses. These exams test your problem-solving abilities to a significantly greater degree than either the Maths or Further Maths A-level.

The most popular tests used by universities are:

Mathematics Admissions Test (MAT)

A 2-hour 30-minutes examination drawing on the A-level Maths (*not* Further Maths) syllabus. Question 1 is formed of 10 multiple choice problems and the remaining questions are split up depending on whether the applicant wishes to study Mathematics, Mathematics & Statistics, Mathematics & Philosophy, Computer Science etc.

You can find the syllabus, past papers, past paper solutions and more by following the link below:

https://www.maths.ox.ac.uk/study-here/undergraduate-study/maths-admissions-test

Sixth Term Examination Paper (STEP)

Three papers are written each year, drawing on the entire Maths and Further Maths syllabus. STEP I is the easiest, STEP II is more challenging, and STEP III is the hardest. The time allowed for each paper is 3 hours and the grades given are:

- S – Outstanding
- 1 – Very Good
- 2 – Good
- 3 – Satisfactory
- U – Unclassified.

Follow the link at the end of this section to find resources for STEP preparation, including:

- A link to a topic-based STEP database
- A link to the *STEP Support Programme*

https://www.admissionstesting.org/for-test-takers/step/preparing-for-step/

Test of Mathematics for University Admission (TMUA)

Two 75-minute papers consisting of 20 multiple choice questions.

Paper 1: Mathematical Thinking, tests your ability to apply your existing knowledge in new situations whereas *Paper 2: Mathematical Reasoning* focuses on your application of logic. Scores are given between 1.0 (lowest) and 9.0 (highest). In most cases TMUA is not compulsory however a good performance can result in a reduced offer.

Follow the link below to find past papers, past paper solutions and more.

https://www.admissionstesting.org/for-test-takers/test-of-mathematics-for-university-admission/preparation/

Advanced Extension Award in Mathematics (AEA)

A 3 Hour paper released by Edexcel as an extension to the usual Maths A-level (no Further Maths content). The problems in these papers are closer in structure to A-level questions but require more sophisticated algebraic manipulation and problem-solving.

You can find past papers and marks schemes for the old specification here:

https://qualifications.pearson.com/en/qualifications/edexcel-a-levels/advanced-extension-award-mathematics-2008.coursematerials.html#%2FfilterQuery=Pearson-UK:Category%2FExam-materials

and extended solutions to selected papers here:

https://warwick.ac.uk/fac/sci/statistics/courses/aea/

2.3 Entry Requirements

Below are the UK Russel Group Universities (ranked according to The Complete University Guide) and course links. These entry requirements are just for the BSc Mathematics; entry requirements for similar courses, such as the MMath, may be different.

Remember that there are loads of other great universities out there, so check out The Complete University Guide or just google studying your subject at university.

It is entirely recommended to take both A-Level Mathematics and Further Mathematics to study mathematics at university. Some universities, however, will still accept you with a suitable score in an admissions test.

Name and Rank	Entry Requirements	Entry Exam Required/Reduced Offer
1. University of Oxford	A*A*A with the A*s in Maths and Further Maths	MAT (Required)
2. University of Cambridge	A*A*A with the A*s in Maths and Further Maths	1 in Step II and III (Required)
3. Durham University	A*A*A with the A*s in Maths and Further Maths	Suitable score in TMUA or MAT or 1 in any STEP will lead to a reduced offer of A*AA with the A* in Maths
4. Imperial College London	A*A*A with the A*s in Maths and Further Maths	Suitable Score in MAT or 2 in any STEP II or III (Required)

5. University of Warwick	A*A*A* with the A*s in Maths and Further Maths	1 in any STEP will lead to a reduced offer of A*A*A with A*s in Maths and Further Maths
6. University College London	A*A*A with the A*s in Maths and Further Maths	2 in any STEP or a Distinction in the AEA will lead to a reduced offer of A*AA with the A* in Maths
7. University of Birmingham	AAA including both Maths and Further Maths	2 in any STEP *will* lead to a reduced offer of AAB with the As in Maths and Further Maths
8. University of Glasgow	AAB to BBB	N/A
9. University of Nottingham	A*AA or AAA or A*AB	Suitable score in TMUA or MAT or any STEP *may* lead to a reduced offer
10. University of Bristol	A*A*A with A* in Maths and A* in mathematics-related subject or A*AA with A* in Maths and A in Further Maths	N/A
11. Queen's University Belfast	AAB with A in Maths or A*BB with an A* in Maths	N/A

12. University of Manchester	A*AA with A* in Maths or AAA with As in Maths and Further Maths	N/A
13. University of Leeds	AAA or A*AB with A in Maths or AAB/A*BB with Further Maths	N/A
14. London School of Economics and Political Science	A*AA with A* in Maths Further Maths highly recommended	Suitable TMUA score *may* lead to a reduced offer
15. University of Exeter	AAA or AAB with A in Maths	N/A
16. University of Southampton	AAA with A in Maths	Suitable score in TMUA or MAT or 2 in any STEP will lead to a reduced offer of AAB with the A in Maths
17. University of Sheffield	AAB with A in Maths	Suitable Score in TMUA or 3 in any STEP may lead to a reduced offer
18. King's College London	AAA or A*AB with As in Maths and Further Maths	N/A

19. University of York	AAA with an A in Maths or AAB with As in Maths and Further Maths	N/A
20. Cardiff University	AAB or ABB with an A in Maths	N/A
21. Newcastle University	AAB or A*BB with A in Maths	N/A
22. University of Liverpool	ABB with A in Maths	N/A
23. Queen Mary	AAA with A in Maths. Further Maths recommended	N/A

3. Interesting MOOCs

Another great way of learning more about mathematics and demonstrating your interest is to take a MOOC, or Massive Open Online Course. These are free courses delivered by universities that you can take online.

Class Central

An excellent place to start is https://www.classcentral.com/ which has links to online courses offered by

- The Hong Kong University of Science and Technology
- Stanford University
- Dehradun University
- The Santa Fe Institute

Among many others. You can also find courses delivered by these institutions by visiting their websites directly. Many of the courses are delivered with either an engineering or computer science focus, which is often a nice way to begin learning a topic.

MIT Open Courseware

For more pure mathematics options you can also visit MIT Open Courseware (run by the Massachusetts Institute of Technology). A great deal of university mathematics has no pre-requisite in A-level Maths or Further Maths. This means you can pick up the basics in quite a few university topics without much previous study.

Follow the link below, select a sub-topic and look for *undergraduate* level courses. Check in the course description for words like *introduction* or *basics* to find a suitable course.

https://ocw.mit.edu/courses/find-by-topic/#cat=mathematics

Courses that stand out are:

- Multivariable Calculus (Fall 2010)

- Theory of Numbers (Spring 2012)
- The Art of Counting (Spring 2003)
- Introduction to MATLAB (Spring 2008)
- Differential Equations (Fall 2011)
- Mathematics For Computer Science (Fall 2010)
- Logic I (Fall 2009)

Do not be too worried if you cannot *complete* them! Just learning a little bit will really make you stand out.

4. Further Reading

Reading some relevant books or articles is a really great way to demonstrate your passion for mathematics in your personal statement and show how you've gone beyond the curriculum. Plus, if you really want to spend three years or more studying mathematics at university, it should be enjoyable! Try taking notes and jotting down your thoughts as you are reading so that you can share some of this in your personal statement.

Books

There are a huge number of popular books on mathematics. Below are just a few – maybe pick a title you like the sound of or search for a different book yourself.

- Game Theory: A Nontechnical Introduction by *Morton D. Davis* - a book that introduces the ideas around game theory using a basis of intuition with a focus on payoff matrices. It uses numeric examples and questions across a wide range of scenarios in a way that those who have a good logical mind will enjoy puzzling out, with enough real world links that you will start to see the outcomes presented play out in reality.
- The Road to Reality by *Roger Penrose* – You'd have to be very ambitious to read this whole book. It's over 1000 pages long and takes you right up to some of the most sophisticated ideas in Mathematics and Physics. Despite this, the book is excellent introduction to some more advanced mathematical ideas and their applications in modern theoretical physics. You will not find a better introduction to mathematical physics at this level.
- The Code Book by *Simon Singh* - The Code Book is a fascinating look at the history of cryptography - the study of codes and the sending of

encrypted messages - and the maths on which it depends. The book will take you from the simple ciphers of the ancients, all the way through to modern-day internet communication, which is only kept secure due to the mathematical properties of prime numbers.

- From Calculus to Chaos by *David Acheson* - What is calculus really for? This book is a highly readable introduction to applications of calculus, from Newton's time to the present day. These often involve questions of dynamics, i.e., of how--and why--things change with time. Problems of this kind lie at the heart of much of applied mathematics, physics, and engineering.
- A History of Mathematics by *Carl B. Boyer* - Boyer and Merzbach distill thousands of years of mathematics into this fascinating chronicle. From the Greeks to Godel, the mathematics is brilliant; the cast of characters is distinguished; the ebb and flow of ideas is everywhere evident. And, while tracing the development of European mathematics, the authors do not overlook the contributions of Chinese, Indian, and Arabic civilizations.
- Infinity: The Quest to Think the Unthinkable *by Brian Clegg* - Infinity is a concept that fascinates everyone from a seven-year-old child to a maths professor. So remarkable and strange is it that contemplating it has driven at least two great mathematicians over the edge into insanity. Where did the concept of infinity come from? Who were the people who originally defined and later refined this paradoxical quantity? Why is infinity, a concept we can never experience or truly grasp, at the heart of science? How can some infinities be bigger than others?
- The Millenium Problems by *Keith David* - In 2000, the Clay Foundation announced a historic competition: whoever could solve any of seven extraordinarily difficult mathematical problems, and have the solution

acknowledged as correct by the experts, would receive 1 million in prize money. Keith Devlin, renowned expositor of mathematics and one of the authors of the Clay Institute's official description of the problems, here provides the definitive account for the mathematically interested reader.

Magazines

- *Quanta Magazine* has columns on physics, mathematics, biology, and computer science. The articles cover both contemporary and historical mathematics as well as more general mathematical themes.
- *Pi in the Sky* is an *excellent* journal written by mathematicians and mathematics students, mostly covering relatable university mathematics for secondary school students. Editions are issued every two years (there are currently twenty-one) and include a set of problems at the end. The solutions are given at the end of the *next issue* so you'll have to wait until 2021 to find the answers to the 2019 problems!

https://www.pims.math.ca/resources/publications/pi-sky

5. Useful Additional Resources

There are loads of other great things out there that you might want to look at to develop your interest and strengthen your application, from videos to podcasts, to websites. Here are a few suggestions:

Oxford University Mathematics Course Materials

Here you can find the entire collection of lecture notes and problem sets for the mathematics modules taught at Oxford:

https://courses.maths.ox.ac.uk/overview/undergraduate

The “Introduction to University Mathematics” course is a good introductory course:

https://courses.maths.ox.ac.uk/node/43812/materials

Better Explained

A unique website that offers a different way of understanding abstract concepts in mathematics. Better Explained provides intuitive, visual explanations of key concepts in maths, from trigonometry to calculus and much more.

https://betterexplained.com

Have a look at a deep exploration of Euler’s relation:

https://betterexplained.com/articles/intuitive-understanding-of-eulers-formula/

Or perhaps learn something new, like what a Fourier Transform is:

https://betterexplained.com/articles/an-interactive-guide-to-the-fourier-transform/

YouTube Channels:

NumberPhile:
A collection of wonderfully produced, engaging and interesting mathematics videos on a huge range of topics.

https://www.youtube.com/channel/UCoxcjq-8xIDTYp3uz647V5A.

Some of the most interesting include:

- Summing Divergent Series
  https://www.youtube.com/watch?v=w-I6XTVZXww
- Different Sizes of Infinity
  https://www.youtube.com/watch?v=elvOZm0d4H0&t=33s
- Problems with 0
  https://www.youtube.com/watch?v=BRRolKTlF6Q
- Zeno's Paradox
  https://www.youtube.com/watch?v=u7Z9UnWOJNY

Vsauce:

Vsauce makes all sorts of videos on interesting physical and mathematical ideas.
https://www.youtube.com/channel/UC6nSFpj9HTCZ5t-N3Rm3-HA.

Some of the best include:

- Supertasks
  https://www.youtube.com/watch?v=ffUnNaQTfZE
- How to Count Past Infinity
  https://www.youtube.com/watch?v=SrU9YdoXE88
- The Banach-Tarski Paradox
  https://www.youtube.com/watch?v=s86-Z-CbaHA
- Is Your Red the Same as My Red?
  https://www.youtube.com/watch?v=evQsOFQju08

3Blue1Brown:

A more advanced mathematical YouTube channel which can introduce you to some university level mathematical concepts in an engaging way. A great idea to get a look ahead at some of the fascinating areas of mathematics you will encounter in a mathematics degree.

https://www.youtube.com/channel/UCYO_jab_esuFRV4b17AJtAw

- Essence of Linear Algebra Series
  https://youtu.be/fNk_zzaMoSs

- Essence of Calculus Series
  https://youtu.be/WUvTyaaNkzM

Mathologer:
Another YouTube channel which deals with some harder topics. These will require you to pay attention, but they are very rewarding and interesting if you do.
https://www.youtube.com/channel/UC1_uAIS3r8Vu6JjXWvastJg

Here is an excellent video about the Riemann Paradox:
https://www.youtube.com/watch?v=-EtHF5ND3_s

Podcasts:

Breaking Math:
45-minute episodes on a range of interesting mathematical topics, explained in an accessible way. You can dip into a bit of chaos theory, artificial intelligence, and loads more maths-related topics relevant to the modern world.

Mr Burgess Maths:
Short 10-20-minute episodes introducing you to mathematics told from a historical perspective. In this podcast you can learn about the mathematical giants of history, and how people developed the mathematics you learn today.

Mathematically Speaking:
A mixture of historical and philosophical episodes all about mathematics. Here you can learn about what we think maths is, how we should understand infinity, and how ancient civilisations sowed the seeds for the development of mathematics.

A Brief History of Mathematics:

A BBC production hosted by the excellent Marcus du Sautoy. The episodes are only around 15 minutes long and introduce you to the development of modern mathematics from Newton to the present day. Each episode focuses on a historical mathematician and describes their interesting lives and mathematical achievements. Take Evariste Galois for example: this mathematician founded an entire branch of mathematics before he died in a duel at just 20.

6. Related courses

At university, there are loads of different combinations of subjects that you can do. Maybe you might find one of these alternatives more interesting? There are many different degrees which a university might offer, including Pure or Applied Mathematics, Mathematics with Physics or Mathematics with Philosophy. Often, you will be able to take a joint-honours with Mathematics and many other subjects, including a language.

A few ideas are listed below with a sample link, but in most cases there are lots of universities that offer these different combinations so make sure to have a good look around!

Mathematics and Physics (e.g. Warwick)

Mathematics and Philosophy (e.g. Oxford)

Mathematical Economics (e.g. LSE)

Natural Sciences (with a Mathematics Option) (e.g. Durham)

Mathematics, Statistics and Data Science (e.g. Bath)

Mathematics with Modern Languages (e.g. UCL)

Mathematics and Computer Science (e.g. Imperial)

7. Example Interview Questions

As you will know, applicants to Oxford, Cambridge and many other universities must take an interview in order to get a place. It is normal to get open-ended questions, as well as being given charts or pieces of writing to analyse if you are applying for Mathematics with another subject.

Remember, you are not supposed to know the answer! They are looking to see whether you can write something sensible down when faced with a difficult question.

What you should be able to do is write down a few equations or sketches that will help you, the interviewer will then provide guidance and suggestions. They deliberately choose topics that they think no one will have studied to make the questions fair. They are looking for how you react under pressure, and how you can present your ideas and your logic. Also, they are interested in whether you are someone they can teach, so treat the interview a bit like a one-on-one lesson.

Ask specific questions if you need some clarification and make it clear to the interviewer what your thought process is so that they can help you if they need to.

In general, there are two kinds of interview you can have. One kind of interview is where you will be asked a very open-ended question that's difficult to solve. You're not necessarily supposed to end up solving the problem yourself. The strategy for this kind of problem is to break down it down into simpler steps and write some sensible starting points down. Your interviewer will then guide you toward a solution based on what you've come up with.

The other kind of interview you can get (usually you get more than one interview) is one where you'll be introduced to some new, first-year undergraduate level material. In this case you're not supposed to have encountered the material before, and the interviewer is looking to see how well you can pick up new material and how you respond to their tuition.

The aim here is to listen to what the interviewer is telling you, asking questions if you need clarification.

While it's difficult to demonstrate what the second kind of interview is like, here is a sample of the kind of open-ended questions you might get asked.

- Differentiate x^x, then sketch its graph.
- A cannon is pointed straight at a monkey hanging from a branch in a tree. The monkey lets go and falls towards the ground at the same instant the cannon is fired. Will the monkey be hit? Describe any assumptions you make.
- Prove, by contradiction, that when $x^2 + y^2 = z^2$ has whole number solutions that x and y cannot both be odd.
- What is the square root of i?
- If you have n non-parallel lines in a plane, how many points of intersection are there?
- If we have 25 people, what is the likelihood that at least one of them is born each month of the year?
- Differentiate $y = x$ with respect to x^2
- Imagine a ladder leaning against a vertical wall with its feet on the ground. The middle rung of the ladder has been painted a different colour on the side, so that we can see it when we look at the ladder from side on. What shape does that middle rung trace out as the ladder falls to the floor?
- How many zeroes does $30!$ have?
- Is it possible to calculate the circumference of the earth if a satellite is known to be moving above you around the earth at height x metres?
- Which is larger 2^{3333}or 3^{2222}

Imagine a ladder leaning against a vertical wall with its feet on the ground. The middle rung of the ladder has been painted a different colour on the side, so that we can see it when we look at the ladder from the side on. What shape does that middle rung trace out as the ladder falls to the floor?

This question tests whether you can do what mathematicians do, which is to abstract away all the unimportant information and use mathematics to represent what's going on. I'd initially ask the candidate what shape they think will be formed, and then ask them how they can test this hypothesis. They might initially try sketching the ladder at different stages – this is fine, but ultimately what we want is something that we can generalise and that is accurate (you can't be sure that your drawing is that accurate, particularly when you're making a sketch on a whiteboard and don't have a ruler). So eventually they will fall back on maths, and try to model the situation using equations. If they get stuck we would ask them what shape the ladder makes with the wall and floor, and they'll eventually spot that at each stage the ladder is forming a right-angled triangle. Some might then immediately leap to Pythagoras' Theorem and use that to find the answer (which is that it forms a quarter circle centred on the point where the floor meets the wall).

This is a fun question because the answer is typically the opposite of what they expect because they think about the shape the ladder makes when it falls (which is a series of tangents to a curve centred away from the wall and the floor). A nice extension is what happens when we look at a point 1/3 or 2/3 up the ladder.

How many ways are there to cover a 2 x n rectangular grid with 2 x 1 tiles?

The question would typically be posed with the caveat – "I don't expect you to have the answer straight away; try working out the answer when n = 1,2,3,4 say". So here is something to investigate. Maths interviews are usually conducted over a piece of paper, sometimes at a white board and so diagrams will get drawn and the student will find the answers are 1, 2, 3, 5 for the first four cases. Some systematic care may be needed to explain why the fourth answer is 5 and why no sixth solution has been missed.

A relatively comfortable few minutes has been spent on this, but it's also important that the student and I aren't talking at cross-purposes. At this point I usually tell the student the next two answers at 8 and 13 – any thoughts on the emerging pattern? The answer is the Fibonacci sequence – where a term of the sequence is the sum of the previous two eg 8 = 5 + 3, though it's not important if the student hasn't met this before or has

forgotten the name. The next stage of the interview is about understanding why that pattern should be appearing here.

When done with this bit of the interview hopefully the student has taken on board a few new ideas. So the question moves on to: 3 x n rectangular grids and 3 x 1 tiles, to 3 x n rectangular grids and 2 x 1 tiles. Hints will continue to be needed, but also there will be plenty of chance to see just how much the student has taken on board from earlier and how well s/he can adapt what's been learned.

One of the reasons I found this a good question in the past was that its knowledge content is low, no more than GCSE. But its internal complexity is sufficiently difficult to test the brightest students, especially in the final part, whilst also allowing students repeated chances to show what they were learning and share their thinking.