Maths Enrichment Pack

So, you want to study maths at a top university? This pack contains loads of resources to help you extend your learning beyond the syllabus. It also has information about the maths courses on offer at Oxbridge.

# Mathematics at Oxford

Standard Offer: A\*A\*A (A\* in Maths and Further Maths)

Interviewed: 53%

Successful: 18%

Admissions Test: MAT

More information: <http://www.maths.ox.ac.uk/study-here/undergraduate-study/why-oxford>

Mathematicians have always been fascinated by numbers. One of the most famous problems is Fermat’s Last Theorem: ie if n≥3, the equation xn+yn=zn has no solutions with x, y, z all nonzero integers. An older problem is to show that one cannot construct a line of length 3√2 with ruler and compass, starting with just a unit length.

In applied mathematics we use mathematics to explain phenomena that occur in the real world. You can learn how a leopard gets its spots, explore quantum theory and relativity, or study the mathematics of stock markets.

We will encourage you to ask questions and find solutions for yourself. You will need to think mathematically and we begin by teaching you careful definitions so that you can construct theorems and proofs. Above all, mathematics is a logical subject, so you will need to argue clearly and concisely as you solve problems. For some of you, this way of thinking or solving problems will be your goal. Others will want to see what further can be discovered. Either way, it is a subject we want you to enjoy.

As a student at Oxford you are a member of the University, the department, and one of 29 colleges. The University provides libraries (including the Bodleian which has over 11 million books), clubs and societies, and sports' facilities (although colleges also have sports' facilities and their own libraries). The University also provides support for students with disabilities through its Disability Advisory Service, provides bursaries and scholarships for students, and when you graduate your degree will be from the University of Oxford.

Mathematics teaching is shared by colleges (where you'll have tutorials) and the department (where you'll have lectures). Oxford’s collegiate system makes both study, and the day-to-day routine, a very different experience from other universities.

# Mathematics and Computer Science at Oxford

Standard Offer: A\*AA (A\* in Maths or Further Maths)

Interviewed: 57%

Successful: 18%

Admissions Test: MAT

More information: <http://www.maths.ox.ac.uk/study-here/undergraduate-study/why-oxford> <http://www.cs.ox.ac.uk/ugadmissions/>

This joint degree offers the opportunity to combine an appreciation of mathematical reasoning with an understanding of computing. Mathematics is a fundamental intellectual tool in computing, but computing is increasingly used as a key component in mathematical problem-solving.

The course concentrates on areas where mathematics and computing are most relevant to each other, emphasising the bridges between theory and practice. It offers opportunities for potential computer scientists both to develop a deeper understanding of the mathematical foundations of their subject, and to acquire a familiarity with the mathematics of application areas where computers can solve otherwise intractable problems. It also gives mathematicians access to both a practical understanding of the use of computers and a deeper understanding of the limits on the use of computers in their own subject.

The first year and part of the second year of the course are spent acquiring a firm grounding in the core topics from both subjects; students are then free to choose options from a wide range of Mathematics and Computer Science subjects. In the second year students take part in an industry-sponsored group design practical.

# Mathematics and Philosophy at Oxford

Standard Offer: A\*A\*A (A\* in Maths and Further Maths)

Interviewed: 45%

Successful: 18%

Admissions Test: MAT

More information: <http://www.maths.ox.ac.uk/study-here/undergraduate-study/why-oxford> [www.philosophy.ox.ac.uk](http://www.philosophy.ox.ac.uk)

This course brings together two of the most fundamental and widely applicable intellectual skills. Mathematical knowledge and the ability to use it is the most important means of tackling quantifiable problems, while philosophical training enhances the ability to analyse issues, question received assumptions and clearly articulate understanding. The combination provides a powerful background from which to proceed to graduate study in either Mathematics or Philosophy or to pursue diverse careers. Historically, there have been strong links between Mathematics and Philosophy; logic, an important branch of both subjects, provides a natural bridge between the two, as does the philosophy of mathematics.

# Mathematics and Statistics at Oxford

Standard Offer: A\*A\*A (A\* in Maths and Further Maths)

Interviewed: 62%

Successful: 9%

Admissions Test: MAT

More information: <http://www.maths.ox.ac.uk/study-here/undergraduate-study/why-oxford> [www.stats.ox.ac.uk](http://www.stats.ox.ac.uk)

All over the world, human beings create an immense and ever–increasing volume of data, with new kinds of data regularly emerging from science and industry. A new understanding of the value of these data to society has emerged, and with it, a new and leading role for Statistics. In order to produce sensible theories and draw accurate conclusions from data, cutting edge statistical methods are needed. These methods use advanced mathematical ideas combined with modern computational techniques, which require expert knowledge and experience to apply. A degree in Mathematics and Statistics equips you with the skills required for developing and implementing these methods, and provides a fascinating combination of deep and mathematically well-grounded method-building and wide-ranging applied work with data.

# Mathematics at Cambridge

Standard Offer: A\*A\*A + STEP

Successful: 17%

Admissions Test: None

More information: <http://www.maths.cam.ac.uk/>

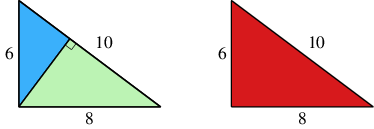
The Cambridge Mathematics course is often considered to be the most demanding undergraduate Mathematics course available in Britain and, correspondingly, one of the most rewarding.

Two other aspects of the course that our students greatly appreciate are its flexibility and the breadth of subjects offered. The amount of choice increases each year and after Year 1 the workload isn’t fixed so you can choose the number of options you study to suit your own work pattern. Some students take as many options as they can; others take fewer and study them very thoroughly.

Maths Enrichment Problems

# Proving Pythagoras’ Theorem

In the left figure below, the blue and green regions have been formed by dropping a perpendicular as shown. How are their areas related to the red area in the right figure?

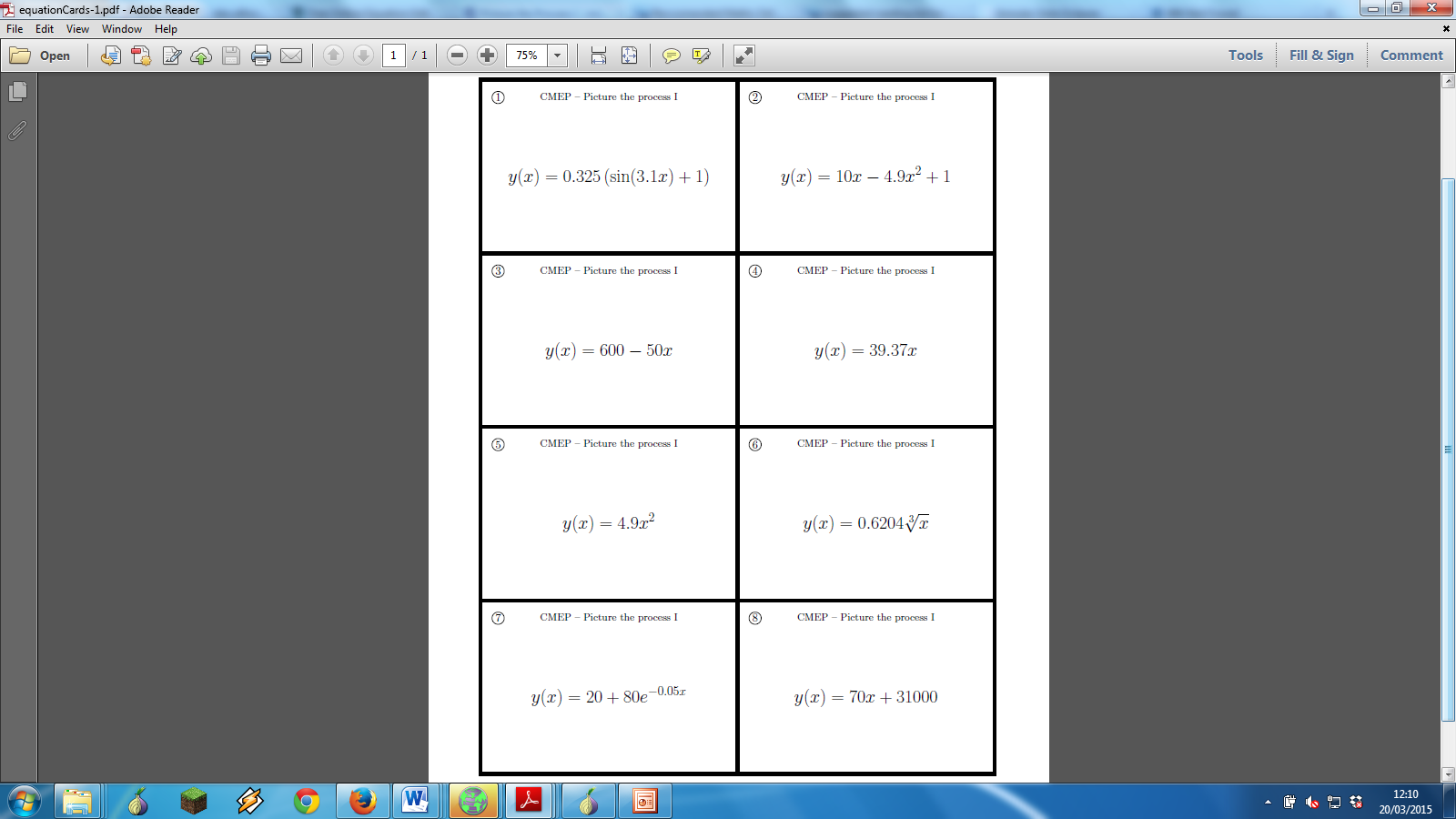


How does this result prove Pythagoras's Theorem?

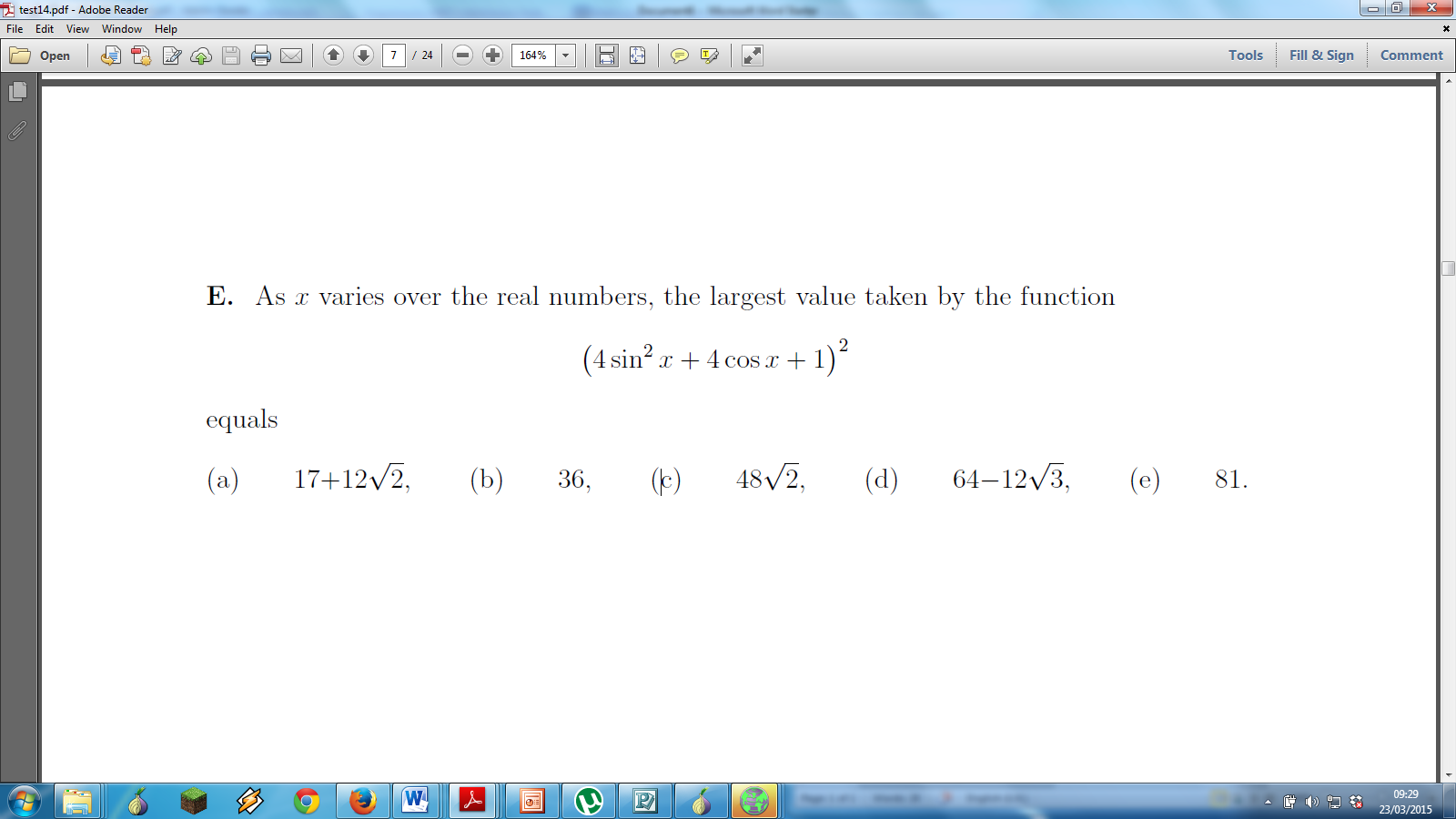
# Graph Sketching

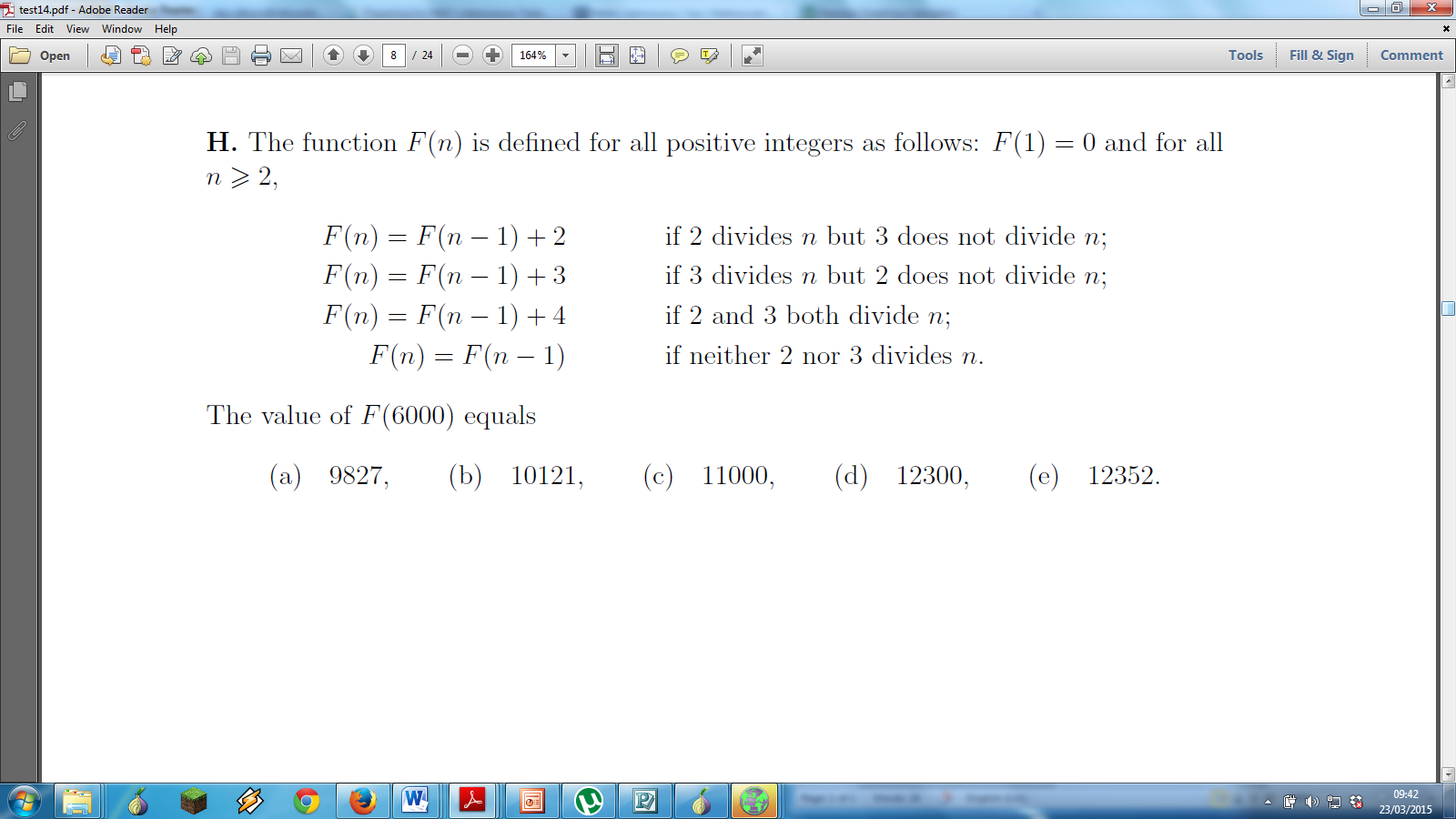
Here are descriptions of eight real-world processes.  For each, try to sketch a suitable graph.  If you are not familiar with the background science, then try to use what you do know to reason through what a graph might look like.  
  
You do not need to calculate or plot exact points, just sketch graphs that give the general shape.  
  
As you produce your sketches, make a list of the features that you are considering.

|  |  |
| --- | --- |
| Temperature of a cup of tea over time. | Height of the valve on a bicycle tyre as the bicycle moves forwards. |
| Height of a tennis ball thrown straight up and then caught. | Distance fallen by a parachutist jumping out of a plane. |
| Reading on the odometer (mile counter) of a car driving on a motorway. | Radius of a spherical balloon as it is inflated. |
| Volume of water remaining in a cup as water is sucked out through a straw. | Distance along a tape measure measured in inches compared with distance measured in metres. |

Below is a possible equation for each process/graph pair (but they're muddled up). Can you match an equation to each process/graph? Can you explain the numbers in these equations? They are all chosen to be physically sensible given suitable units. What might the units be for each process/graph/equation?

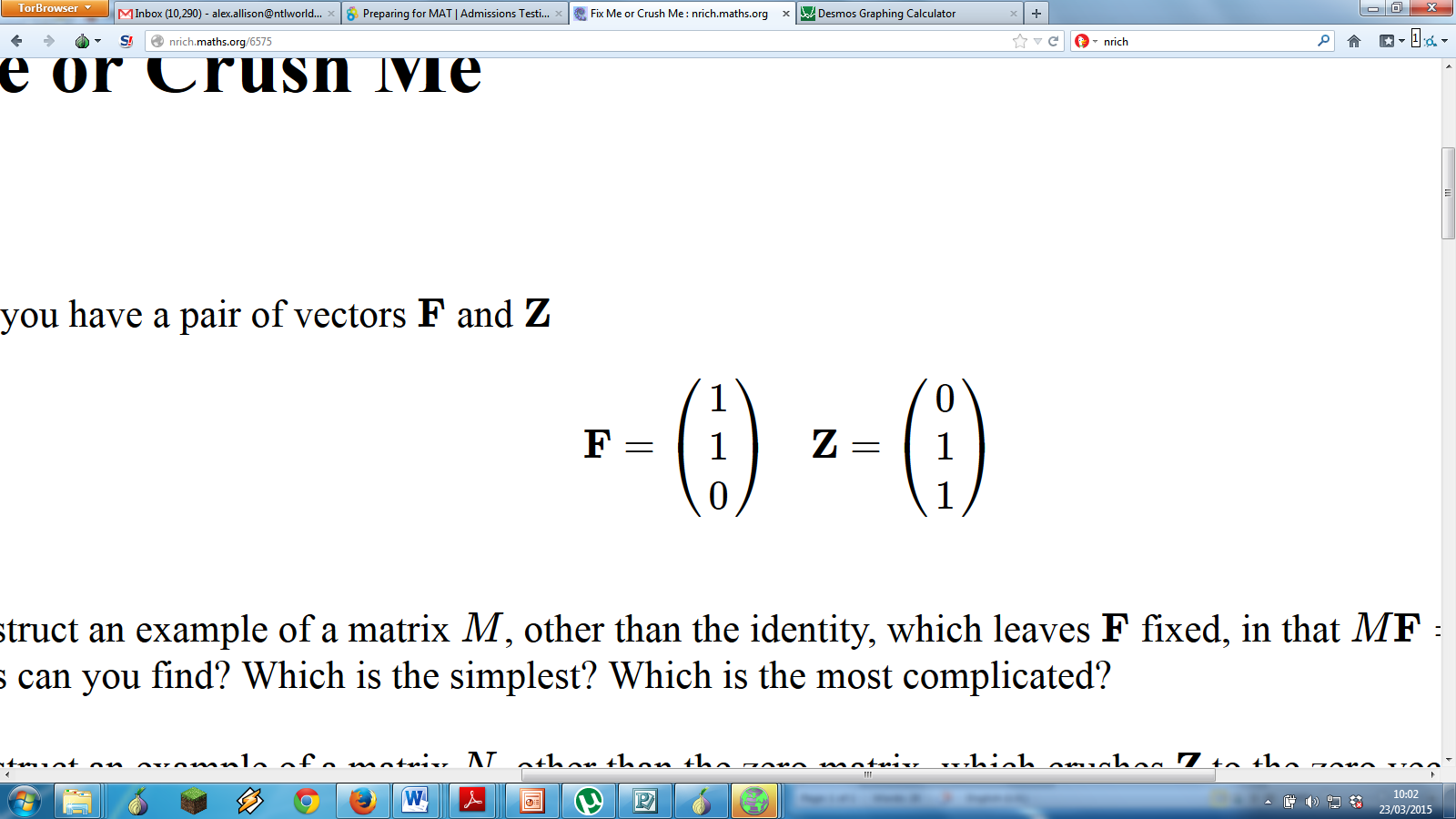
# Interesting Questions from the MAT

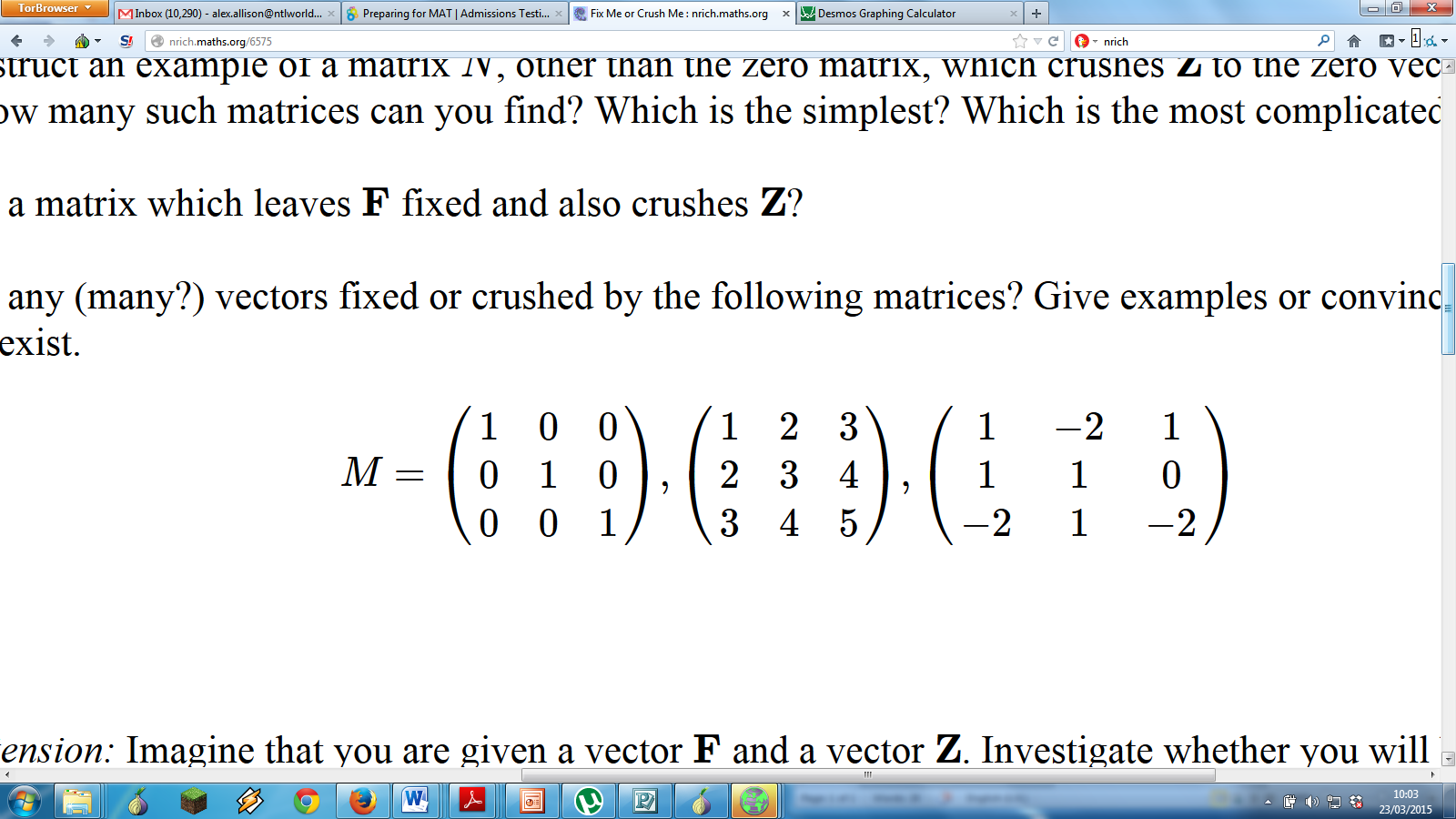




# Vector ‘Fixing’ and ‘Crushing’ (Further Maths)

Imagine that you have a pair of vectors **F** and **Z**

  
Can you construct an example of a matrix *M*, other than the identity, which leaves **F** fixed, in that *M***F**=**F**? How many such matrices can you find? Which is the simplest? Which is the most complicated?  
  
Can you construct an example of a matrix *N*, other than the zero matrix, which crushes **Z** to the zero vector **0**, in that *N***Z**=**0**? How many such matrices can you find? Which is the simplest? Which is the most complicated?  
  
Can you find a matrix which leaves **F** fixed and also crushes **Z**?  
  
Can you find any (many?) vectors fixed or crushed by the following matrices? Give examples or convincing arguments if no such vectors exist.

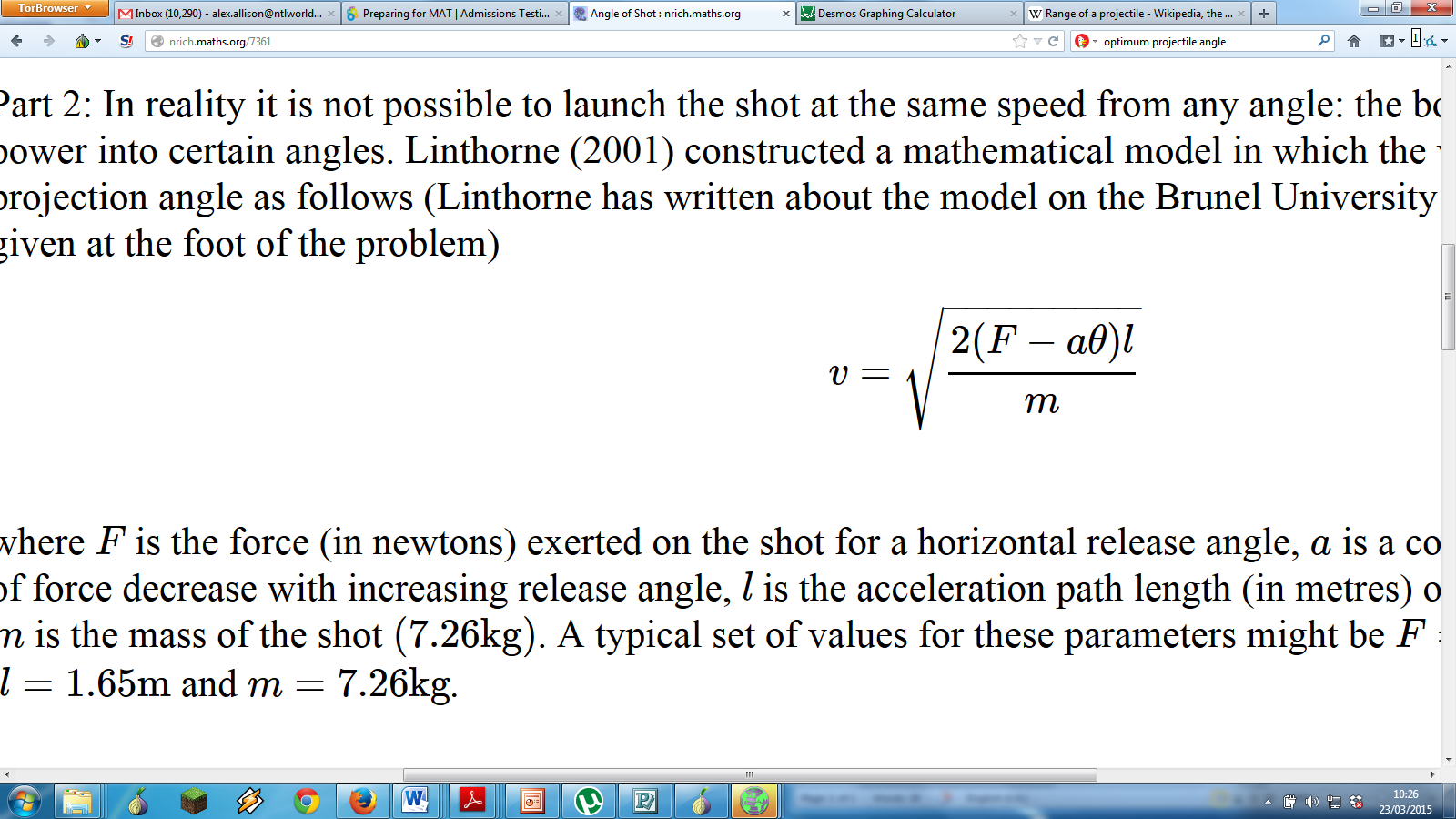
  
  
  
*Very hard extension:* Imagine that you are given a vector **F** and a vector **Z**. Investigate whether you will be able to make a matrix *M* which both fixes **F** and crushes **Z**.

# Angle of Shot

When a projectile is fired, it travels along a parabola (in the absence of wind and air resistance).

Part 1: A shot putter will release the shot from arms length. Estimate the optimal angle that the shot should be released from to make it travel furthest, assuming the the shot putter can launch the shot at the same speed from any angle. (Note: the shot is launched from around head height rather than ground level)

Part 2: In reality it is not possible to launch the shot at the same speed from any angle: the body is naturally able to put more power into certain angles. Linthorne (2001) constructed a mathematical model in which the velocity is related to the projection angle as follows (Linthorne has written about the model on the Brunel University site; the published reference is given at the foot of the problem)



where F is the force (in newtons) exerted on the shot for a horizontal release angle, a is a constant that characterizes the rate of force decrease with increasing release angle, l is the acceleration path length (in metres) of the shot during the delivery and m is the mass of the shot (7.26kg). A typical set of values for these parameters might be F=450N, a=3N/degree, l=1.65m and m=7.26kg.

Determine approximately the angle the shot putter should choose, to maximise the length of the shot put.

The published reference for the paper is Linthorne, N. P. (2001). Optimum release angle in the shot put. Journal of Sports Sciences, 19, 359–372.

# Trigonometry and Modulus Function

For this question, you need to know that |sinx| is known as the modulus of sinx. It has the sam value as sinx, but is always positive. To calculate |sinx|, evaluate sinx. If it is positive |sinx|=sinx, if it is negative, |sinx|=-sinx. The same is true for whatever expression is in-between the lines.

You also need to know the multiple angle formulae. These give expressions for cos(A+B) and sin(A+B) in terms of cosA, cosB, sinA and sinB. They are:

sin(A+B)=sinAcosB+cosAsinB

sin(A-B)=sinAcosB-cosAsinB

cos(A+B)=cosAcosB-sinAsinB

cos(A-B)=cosAcosB+sinAsinB

(1) Plot the graph of the function y=f(x) where f(x)=sinx+|sinx|. Find the first derivative of this function and say where it is defined and where it is not defined.

(2) Express the function f(x)=sinx+cosx in the form f(x)=Asin(x+α), find A and α and plot the graph of this function. Similarly express the function g(x)=sinx−cosx in the form g(x)=Bsin(x+β) where −π/2<β<π/2, and plot its graph on the same axes.

(3) Plot the graph of the function y=f(x) where f(x)=sinx+|cosx|. Find the first derivative of this function and say where it is defined and where it is not defined.

# Probability

Tom and Jane are playing a game in which, on each play,

Tom has a 2/3 chance of winning.

Whoever wins must pay the other one 1 token.

If Tom starts with 1 token and Jane starts with 2, and the game ends when one of them goes broke, what is the probability that each one wins ?

Solution at: <http://www.gottfriedville.net/mathprob/prob-rsgame.html>

Park and Sarah play against each other in tennis, their winning probabilities for each point are 2/3 and 1/3.

What are their chances of winning a game ?

# Recurrence Relation: 3 kinds of sandwiches

Each day Angela eats lunch at a deli, ordering one of the following: chicken salad, a tuna sandwich, or a turkey wrap. Find a recurrence relation for the number of ways for her to order lunch for the "n" days if she never orders chicken salad three days in a row. (Hint: start by investigating small n, then draw a tree diagram)

Solution at <http://www.gottfriedville.net/mathprob/recur-menu.html>

Personal Statement Guide

The UCAS statement forms one of the key pillars of your application to university. It’s 4,000 characters detailing the reasons you feel you would be an ideal candidate for the course. While 4,000 characters may sounds like a lot, in reality it isn’t much more than a side of A4, so it is important to be concise in order to convey your passion and enthusiasm effectively.

# Getting off to a good start

The first paragraph of your personal statement is crucial. A strong opening will grab the interest of the admissions tutor, which is important when you have to stand out in a sea of potential applicants. This is the part of the statement where you have the most scope for creativity. Try and think of an original way of introducing your interest in the subject. I can’t tell you how to be original, but I can tell you what to avoid: tales of how you ‘wanted to do the subject since you were 5’ are unlikely to impress, given the vast number of students who write this every year! Many people try opening with a quote, but I’d advise against this. You want to demonstrate your interest in the subject – using someone else’s words doesn’t send out the best message.

# Getting the right balance

Writing a good personal statement is a balancing act between academic interests and extra-curricular activities. You probably have loads of enrichment activities to talk about, and they may seem more interesting, but don’t fall into the trap of talking about them too much. Your personal statement will be read by a lecturer, and their main priority is selecting students who will be the best academics. They’re not too concerned about what you can bring to the wider university community – they just want the brightest students on their course. I would include a few lines on wider enrichment, to let them know you’re a human and not a subject-loving robot, but keep linking them back to how they make you a better student. Of course, feel free to talk about subject related enrichment such as work experience or summer schools as part of the academic section – this specific experience will really help you stand out from the crowd academically.

The general advice is that your personal statement should be 75% academic, 25% personal. I’d view this as a minimum to aim for - you won’t be disadvantaged for emphasising academic matters more.

# Showing passion

‘Passion’ is the single most overused word in personal statements. Everyone knows that universities are looking for passionate students, but simply stating your passion for the subject over and over isn’t going to demonstrate this. ‘Show, don’t tell’ is the best mantra to use here. Demonstrate your enthusiasm for the subject by talking about wider reading that you’ve done; discuss an area of the subject you’re particularly interested in; show how you’ve extended your learning beyond the syllabus. All of these will give the admissions tutor a far greater indication of your passion than you simply stating it again and again.

# Hitting the books

Talking about the wider reading you’ve done can really enhance a personal statement’s academic credentials. However, there are pitfalls to avoid when discussing wider reading. Firstly, make sure that your material is academically reputable – try to choose the highest level text you’ve read to talk about in detail. Articles from non-specialist sources such as the BBC are probably best avoided. Don’t just name drop lots of books you’ve read, try and discuss the content – anyone can read the words of a book, but tutors want you to demonstrate that you’ve gained a deeper understanding of the subject. Offer an opinion about the content, what did you think was particularly interesting? What was the overall narrative of the text? I’d recommend trying to discuss what you read with peers or teachers, as it is this discussion that will really help you gain insight.

If you’re talking about a magazine or journal you read, try and give a specific example of an article you’ve read. Loads of people applying for economics will say they read The Economist, but if you talk about an article you found interesting this shows that you’re really engaging with it. If you do mention an article though, keep a copy of it somewhere. If you’re invited for interview it may well come up as a talking point, and it’ll be pretty embarrassing if you can’t remember what it was about!

# Don’t be a checklist ticker

You likely feel that there’s a list of things you have to include in your personal statement, such as details of your school subjects, your wider reading and your extra-curricular activities. While this is true to some extent, be careful not to make it seem like you’re ticking off things on a checklist. The idea of fulfilling a list often leads people to include things that just aren’t relevant. Some people feel it necessary to list all of the subjects they’re taking, often creating quite contrived ways to link it to their course. This simply isn’t necessary, as the tutor can see the subjects you’re taking on the form! Unless you have a meaningful point to make, like taking a wide range of subjects to become a well-rounded academic, save the characters.

Again, don’t begin every sentence like you’re ticking an item off the list. Sentence openings like ‘I enjoy lots of wider reading…’ or ‘I am engaged in lots of extra-curricular activities…’ scream of unoriginality. Be creative with your structure and you’ll engage with the admissions tutor much better.

# Getting your point across

You might have a burning passion for the subject, backed up with a wealth of academic enrichment and wider reading, but if you’re not able to effectively utilise language you won’t be able to communicate this effectively. So many people seem to think that the key to writing a good personal statement is to write laboriously rambling sentences. I’ve seen examples of personal statements where sentences run over 3 lines. Not only is this style of writing hard to follow, it’s also pretty boring to read. Honestly, the best advice is to think back to GCSE English and writing to persuade; after all, persuasion is the name of the game. Use a variety of sentence structures, long and short. Don’t cram loads of ideas into one sentence, separate them. Avoid using the same word over and over, but don’t just blindly throw a thesaurus at it.

When you redraft, take the time to rework awkward sentences. Read your statement aloud, and you’ll be able to tell when something doesn’t quite flow right. Simplicity is the key – useless rambling is not only using up valuable characters, but it also dilutes the impact of your statement.

Maths Reading List

# Recommended by The Student Room & MEI

## Cryptography

### The Codebook Simon Singh

Interesting exploration into the different types of codes and cyphers used throughout history. Is a very good general maths book, covering elements of basic number theory, physics, statistics (frequency analysis) and computing. I found it interesting but view it more as an encyclopaedia for reference rather than a comprehensive account.

## The Mathematics of Ciphers S.C. Coutinho

## History of Maths

### A History of Mathematics Carl B. Boyer

### Infinity: The Quest to Think the Unthinkable Brian Clegg

This is definitely one of the better books on the subject. A chronological biography of the concept of infinity, from Greeks to present day.

### E, the Story of a Number Eli Maor

### Six Books of Euclid Oliver Byrne & Werner Oechslin

Created in 1847 by Oliver Byrne, a surveyor on the Falkland Island, this book takes the first six books of Euclid and uses colour to help explain the propositions. The resulting diagrams have the appearance of the abstract art of Mondrian and can be appreciated as much for their aesthetic qualities as for their mathematical ones. A facsimile of the original edition has recently been reprinted.

### Logicomix: An Epic Search for Truth Apostolos Doxiadis & Christos H. Papadimitriou

Logicomix is a graphic novel from the Author of ‘Uncle Petros and Godbach’s Conjecture’ that tells the story of Bertrand Russell and his attempts to establish a logical foundation for mathematics. The result is a highly original and engaging way of communicating some complex ideas

## General Mathematics

### What the Numbers Say: A Field Guide to Mastering Our Numerical World Derrick Niederman and David Boyum

This book looks at situations where it’s important to be able to understand and analyse numerical information. Although many of the contexts are American, it is very readable and will be of particular interest to teachers and students of Core Maths.

### Alex's Adventures in Numberland Alex Bellos

A very accessible and well-written introduction to mathematics written in the style of a travelogue that demonstrates how useful, universal, interesting and beautiful mathematics is.

## Biography

### Abel's Proof: An Essay on the Sources and Meaning of Mathematical Unsolvability Peter Pesic

### Euler : The Master of Us All William Dunham

Arguably Leonhard Euler used ideas from A level Mathematics and Further Mathematics more creatively than anybody else in history. This books explains in detail the ways in which he solved a variety of problems and helps the reader to appreciate what mathematical genius is.

## Mathematical Problems

### The Millenium Problems Keith Devlin

### Journey Through Genius: The Great Theorems of Mathematics William Dunham

### The Equation That Couldn't Be Solved Mario Livio

### Kepler's Conjecture George Szpiro

### Poincaré's Prize George Szpiro

# Cambridge University Reading List

## Historical and General

One of the most frequent complaints of mathematics undergraduates is that they did not realise until too late what was behind all the material they wrote down in lectures: Why was it important? What were the problems which demanded this new approach? Who did it? There is much to be learnt from a historical approach, even if it is fairly non-mathematical.

### Makers of Mathematics, S. Hollingdale (Penguin, 1989)

There are not many books on the history of mathematics which are pitched at a suitable level. Hollingdale gives a biographical approach which is both readable and mathematical. You might also try E.T. Bell Men of Mathematics (Touchstone Books, Simon and Schuster, 1986). Historians of mathematics have a lot to say about this (very little of it complimentary) but it is full of good stories which have inspired generations of mathematicians.

### A Russian Childhood, S. Kovalevskaya (trans. B. Stillman) (Springer, 1978, now out of print)

Sonya Kovalevskaya was the first woman in modern times to hold a lectureship at a European university: in 1889, in spite of the fact that she was a woman (with an unconventional private life), a foreigner, a socialist (or worse) and a practitioner of the new Weierstrassian theory of analysis, she was appointed a professor at the University of Stockholm. Her memories of childhood are non-mathematical but fascinating. She discovered in her nursery the theory of infinitesimals: times being hard, the walls had been papered with pages of mathematical notes.

### Alan Turing, the Enigma, A. Hodges (Vintage, 1992)

A great biography of Alan Turing, a pioneer of modern computing. The title has a double meaning: the man was an enigma, committing suicide in 1954 by eating a poisoned apple, and the German codethat he was instrumental in cracking was generated by the Enigma machine. The book is largely non-mathematical, but there are no holds barred when it comes to describing his major achievement, now called a Turing machine, with which he demonstrated that a famous conjecture by Hilbert is false.

### The Man Who Knew Innity, R. Kanigel (Abacus, 1992)

The life of Ramanujan, the self-taught mathematical prodigy from a village near Madras. He sent Hardy samples of his work from India, which included rediscoveries of theorems already well known in the West and other results which completely baffled Hardy. Some of his estimates for the number of ways a large integer can be expressed as the sum of integers are extraordinarily accurate, but seem to have beenplucked out of thin air.

### A Mathematician's Apology, G.H. Hardy (CUP, 1992)

Hardy was one of the best mathematicians of the first part of this century. Always an achiever (his New Year resolutions one year included proving the Riemann hypothesis, making 211 not out in the fourth test at the Oval, finding an argument for the non-existence of God which would convince the general public, and murdering Mussolini), he led the renaissance in mathematical analysis in England. Graham Greene knew of no writing (except perhaps Henry James's Introductory Essays) which conveys so clearly and with such an absence of fuss the excitement of the creative artist. There is an introduction by C.P. Snow.

### Littlewood's Miscellany (edited by B. Bollobas) (CUP, 1986)

This collection, first published in 1953, contains some wonderful insights into the development and lifestyle of a great mathematician as well as numerous anecdotes, mathematical (Lion and Man is ex- cellent) and not-so-mathematical. The latest edition contains several worthwhile additions, including a splendid lecture entitled `The Mathematician's Art of Work', (as well as various items of interest mainly to those who believe that Trinity Great Court is the centre of the Universe). Thoroughly recommended.

### The man who loved only numbers, Paul Hoffman (Fourth Estate, 1999)

An excellent biography of Paul Erdos, one of the most proli c mathematicians of all time. Erdos wrote over 1500 papers (about 10 times the normal number for a mathematician) and collaborated with 485 other mathematicians. He had no home; he just descended on colleagues with whom he wanted to work, bringing with him all his belongings in a suitcase. Apart from details of Erdos's life, there is plenty of discussion of the kind of problems (mainly number theory) that he worked on.

### Surely You're Joking, Mr Feynman, R.P. Feynman (Arrow Books, 1992)

Autobiographical anecdotes from one of the greatest theoretical physicists of the last century, which became an immediate best-seller. You learn about physics, about life and (most puzzling of all) about Feynman. Very amusing and entertaining.

### Fermat's Last Theorem, Simon Singh (Fourth Estate)

You must read this story of Andrew Wiles's proof of Fermat's Last Theorem, including all sorts of mathematical ideas and anecdotes; there is no better introduction to the world of research mathematics. You must also see the associated BBC Horizon documentary if you get the chance. Singh's later *The Code Book* (Fourth Estate) is not so interesting mathematically, but is still a very good read.

### The Music of the Primes, Marcus du Sautoy (Harper-Collins, 2003)

This is a wide-ranging historical survey of a large chunk of mathematics with the Riemann Hypothesis acting as a thread tying everything together. The Riemann Hypothesis is one of the big unsolved problems in mathematics (in fact, it is one of the Clay Institute million dollar problems) though unlike Fermat's last theorem it is unlikely ever to be the subject of pub conversation. Du Sautoy's book is bang up to date, and attractively written. Some of the maths is tough but the history and storytelling paint a convincing (and appealing) picture of the world of professional mathematics.

### Finding Moonshine: a mathematician's journey through symmetry, Marcus Du Sautoy (Fourth Estate, 2008)

This book has had exceptionally good reviews (even better than Du Sautoy's Music of the Primes listed above). The title is self explanatory. The book starts with a romp through the history and winds up with some very modern ideas. You even have the opportunity to discover a group for yourself and have it named after you.

### Number, J. McLeish (Bloomsbury, 1991)

The development of the theory of numbers, from Babylon to Babbage, written with humour and erudition. Hugely enjoyable.

## Recreational

You can find any number of puzzle books in the shops and some which are both instructive and entertaining are listed here. Other books in this section do not attempt to set the reader problems, but to give an appetising introduction to important areas of, or recent advances in, mathematics.

### http://www.cut-the-knot.org

This web site is absolutely brilliant. If you haven't seen it before, you should take a look immediately. It is like a mathematical labyrinth: you can wander through it for hours (years, probably), following different links. It covers a huge range of mathematics, much of which is elementary (which is not the same as saying it is easy) and all of which is interesting and beautifully presented | see, for example, the 103 essentially different proofs of Pythagoras's theorem.

### The Colossal Book of Mathematics M. Gardner (Norton 2004)

Over 700 pages of Gardner for under 20 pounds is an astonishing bargain. You will be hooked by the very first topic in the book if you haven't seen it before (and probably even if you have): a Diophantine problem involving a monkey and some coconuts | can't say more without writing a spoiler. At the beginning, about 60 other books by Martin Gardner are listed, none of which will disappoint.

### Game, Set and Math. I. Stewart (Penguin, 1997)

Stewart is one of the best current writers of mathematics (recreational or otherwise). This collection (which includes a calculation which shows why you need only be marginally the better player to win a tennis match, hence the title) was originally written in French: some of the puns seem to have suffered in translation, but the joie de vivre shines through. You might also like Stewart's book on Chaos, Does God Play Dice? (Penguin, 1990). Excellent writing again but, unlike the chaos books mentioned below, no colour pictures. The title is a quotation from Einstein, who believed (probably incorrectly) that the answer was no; he thought that theories of physics should be deterministic, unlike quantum mechanics which is probabilistic.

### To Innity and Beyond Eli Maor (Princeton, 1991)

Not much hard mathematics here, but lots of interesting mathematical ideas (prime numbers, irrationals, the continuum hypothesis, Olber's paradox (why is the sky dark at night?) and the expanding universe to name but a few), fascinating history and lavish illustrations. The same author has also written a whole book about one number (e The Story of a Number), also published by Princeton (1994), but not yet out in paperback.

### A Mathematical Mosaic Ravi Vakil (Mathematical Association of America, 1997)

This is a bit unusual. I can't do better than to direct you to the web site http://www.maa.org/pubs/books/mtm.html

It is not easy to get hold of (see also this website); but it is not expensive and I think it is brilliant. Don't be discouraged by the profiles of exceptional young mathematicians - they are exceptional!

## Readable Mathematics

### How to Think like a Mathematician Kevin Houston (CUP, 2009)

This sounds like the sort of book that elderly people think that young people should read. However, there is lots of good mathematics in it (including many interesting exercises) as well as lots of good advice. How can you resist a book the first words of which (relating to the need for accurate expression) are:

Question: How many months have 28 days?

Mathematician's answer: All of them.

### The MαTH ßOOK Clifford A Pickover (Sterling, 2009)

The subtitle is `From Pythagoras to the 57th Dimension, 250 Milestones in the History of Mathematics'. Each left hand page has a largely non-mathematical description of one of the great results in mathematics and each right hand page has a relevant illustration. There is just enough mathematical detail to allow you to understand the result and pursue it (if you fancy it), via google. The book is beautifully produced. The illustration for the page on Russell and Whitehead's Principia Mathematica, said here to be the 23rd most important non-fiction book of the 20th century, is the proposition occurring several hundred pages into the book, that 1 + 1 = 2.

### Mathematics: a very short introduction Timothy Gowers (CUP, 2002)

Gowers is a Fields Medalist (the Fields medal is the mathematical equivalent of the Nobel prize), so it is not at all surprising that what he writes is worth reading. What is surprising is the ease and charm of his writing. He touches lightly many areas of mathematics, some that will be familiar (Pythagoras) and some that may not be (manifolds) and has something illuminating to say about all of them. The book is small and thin: it will fit in your pocket. You should get it.

### Solving Mathematical Problems Terence Tao (OUP, 2006)

Tao is another Fields Medalist. He subtitles this little book `a personal perspective' and there is probably no one better qualified to give a personal perspective on problem solving: at 13, he was the youngest ever (by some margin) gold medal winner in International Mathematical Olympiad. There are easy problems (as well as hard problems) and good insights throughout. The problems are mainly geometric and algebraic, including number theory (no calculus).

### The Pleasures of Counting T.W. Korner (CUP, 1996)

A brilliant book. There is something here for anyone interested in mathematics and even the most erudite professional mathematicians will learn something new. Some of the chapters involve very little technical mathematics (the discussion of cholera outbreaks which begins the book, for example) while others require the techniques of a first or second year undergraduate course. However, you can skip through the technical bits and still have an idea what is going on. You will enjoy the account of Braess's paradox (a mathematical demonstration of the result, which we all know to be correct, that building more roads can increase journey times), the explanation of why we should all be called Smith, and the account of the Enigma code{breaking. These are just a few of the topics Korner explains with enviable clarity and humour.

### Calculus of the Ambitious T.W. Korner (CUP, 2014)

You can and should supplement your sixth-form calculus with Korner's latest offering. You will find here some familiar ideas seen from an unfamiliar angle and almost certainly much that is unfamiliar; multivariable calculus for example (when functions depend on more than one variable). This excerpt from introduction gives you a flavour of the style: When leaving a party, Brahms is reported to have said `If there is anyone here whom I have not offended tonight, I beg their pardon. If any logician, historian of mathematics, numerical analyst, physicist, teacher of pedagogy or any other sort of expert picks up this book to see how I have treated their subject, I can only repeat Brahms apology.

### What is Mathematics? R. Courant & H. Robbins (OUP, 1996)

A new edition, revised by Ian Stewart, of a classic. It has chapters on numbers (including 1), logic, cubics, duality, soap-films, etc. The subtitle (An elementary approach to ideas and methods) is rather optimistic: challenging would be a more appropriate adjective, though interesting or instructive would do equally well. Stewart has resisted the temptation to tamper: he has simply updated where appropriate - for example, he discusses the solution to the four colour problem and the proof of Fermat's Last Theorem.

### From Here to Infinity Ian Stewart (OUP, 1996)

This is a revised version of Problems in Mathematics (1987); revised of necessity, as the author says, because some of the problems now have solutions - an indication of the speed at which the frontiers of mathematics are receding. Topics discussed include solving the quintic, colouring, knots, infinitesimals, computability and chaos. In the preface, it is guaranteed that the very least you will get from the book is the understanding that mathematical research is not just a matter of inventing new numbers; what you will in fact get is an idea of what real mathematics is.

### What's Happening in the Mathematical Sciences B. Cipra (AMS, 1993, '94, '96, '99, '02)

This really excellent series is published by the American Mathematical Society. It contains low(ish)-level discussions, with lots of pictures and photographs, of some of the most important recent discoveries in mathematics. Volumes 1 and 2 cover recent advances in map{colouring, computer proofs, knot theory, travelling salesmen, and much more. Volume 3 (1995-96) has, among other things, articles on Wiles' proof of Fermat's Last Theorem, the investigation of twin primes which led to the discovery that the Pentium chip was wed, codes depending on large prime numbers and the Enormous Theorem in group theory (the theorem is small but the proof, in condensed form, runs to 5000 pages). Exciting stuff.

### Archimedes' Revenge P. Hoffman (Penguin, 1991)

This is not a difficult read, but it covers some very interesting topics: for example, why democracy is mathematically unsound, Turing machines and travelling salesmen. Remarkably, there is no chapter on chaos.

### The Mathematical Experience P.J. Davis & R. Hersh (Penguin, 1990)

This gives a tremendous foretaste of the excitement of discovering mathematics. A classic.

### Beyond Numeracy J. A. Paulos (Penguin, 1991)

Bite-sized essays on fractals, game-theory, countability, convergence and much more. It is a sequel to his equally entertaining, but less technical, Numeracy.

### The Penguin Dictionary of Curious and Interesting Numbers D.Wells (Penguin,1997)

A brilliant idea. The numbers are listed in order of magnitude with historical and mathematical in formation. Look up 1729 to see why it is `among the most famous of all numbers'. Look up 0.740 to discover that this is the density of closely-packed identical spheres in what is believed by many mathematicians (though it was at that time an unproven hypothesis) and is known by all physicists and greengrocers to be the optimal packing. Look up Graham's number (the last one in the book), which is inconceivably big: even written as a tower of powers it would take up far more ink than could be made from all the atoms in the universe. It is an upper bound for a quantity in Ramsey theory whose actual value is believed to be about 6. A book for the bathroom to be dipped into at leisure. You might also like Wells's The Penguin Dictionary of Curious and Interesting Geometry (Penguin, 1991) which is another book for the bathroom. It is not just obscure theorems about triangles and circles (though there are plenty of them); far-reaching results such as the hairy ball theorem (you can't brush the hair flat everywhere) and fixed point theorems are also discussed.

### New Applications of Mathematics C. Bondi (ed.) (Penguin, 1991)

Twelve chapters by different authors, starting with functions and ending with supercomputers. There is material here which many readers will already understand, but treated from a novel point of view, and plenty of less familiar but still very understandable material.

### The New Scientist Guide to Chaos N. Hall (ed.) (Penguin, 1991)

This comprises a series of articles on various aspects of chaotic systems together with some really amazing photographs of computer-generated landscapes. Chaos is what happens when the behaviour of a system gets too complicated to predict; the most familiar example is the weather, which apparently cannot be forecast accurately more than five days ahead. The articles here delve into many diverse systems in which chaos can occur and include a piece by the guru (Mandelbrot) and one about the mysterious new constant of nature discovered by Feigenbaum associated with the timescale over which dynamical systems change in character.

### Chaos J. Gleick (Minerva/Random House, 1997)

Sometimes, at interview, candidates are asked whether they have read any good mathematics books recently. There was a time when nine out of ten candidates who expressed a view named this one. Before that, it was Douglas Hofstadter's Godel, Escher, Bach (Penguin, 1980). Surely they couldn't all have been wrong?

### Fractals. Images of Chaos H. Lauwerier (Penguin, 1991)

Poincaire recurrence, Julia sets, Mandelbrot, snow flakes, the coastline of Norway, nice pictures; in fact, just what you would expect to find. But this has quite a bit of mathematics in it and also a number of programs in basic so that you can build your own fractals. It is written with the energy of a true enthusiast.