What have mathematicians done for us?







GRESHAM COLLEGE







Some common views on maths and mathematicians

Mathematics is completely useless Mathematicians are evil souless geeks All Mathematicians are mad!





🕓 8 May 2016 | US & Canada

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This can cause serious problems



Flight delayed after passenger becomes suspicious of equation

E = C + dD = C + D = C +

An Italian economist says his flight was delayed after a fellow passenger saw him working on a differential equation and alerted the cabin crew.

Guido Menzio was taken off and questioned by agents who did not identify themselves, after the woman next to him said she felt ill. And it is completely false

The modern world would not exist without maths Maths lies at the heart of all modern technology





Much of industry has problems which can potentially be formulated, and solved using mathematics

Maths connects with all areas and knows no bounds or constraints!



Too few people recognize that the high technology so celebrated today is essentially a mathematical technology

Edward David, ex-president of Exxon R&D

Spot the mathematician, and why are they important?



Maxwell and the discovery of electromagnetic waves

$$\nabla \times E = -\frac{\partial B}{\partial t} - M, \quad \nabla \times H = -\frac{\partial D}{\partial t} + J,$$
$$\nabla D = \rho, \quad \nabla B = 0.$$

Electromagnetism, radio, WiFi,TV, radar, mobile phones, microwaves all come from the work of Maxwell!



Lie





So ... where do good problems come from?

Traditional industrial users of maths are

Telecommunications, aerospace, power generation, iron and steel, mining, oil, weather forecasting, security, finance

But they could equally well be ...

Retail, food, zoos, sport, entertainment, graphic design, media, forensic service, hospitals, air-searescue, education, transport, risk, health, biomedical, environmental agencies, art, ...







All lead to great and diverse problems. Many/most of which can be tackled or illuminated using math

Good maths (to help solve)

Hard applied problems

(Leads to) More good maths



(Which can help to solve) More hard applied problems

Which can often seem to have no relation at all to the original ones!

So .. Let's see how this process works throughout history

- 1. Early maths
- 2. Recreational maths
- 3. Maths tells us where we are
- 1. Maths saves lives
- 2. Maths helps us communicate
- 3. Where next?



1. Early maths and the tax man

Early people counted on their fingers. This led to the natural numbers 1,2,3,4,5



Numbers recorded on Babylonian cuneiform tablets Later on numbers were expanded to include zero, negative numbers (debt) and fractions

1, 0, -1, -2, 3/5, 7/8, 9/7, ...

Problems posed such as: I have 7 cows, the taxman takes 5, how many do I have now.



Called **DISCRETE**. Still very important in digital electronics

Later on numbers extended to real numbers to allow solutions of other equations such as the quadratic equation



 $x^2 = 2$

Early calculation of the square root of 2 = 1.41421356....

Important to the taxman to work out the area of fields!

Problems posed in real numbers are called continuous. Most problems in nature are like this

Tackled using calculus (around 1690)

Best tool that we have for understanding the patterns that we see in the real world



2. Recreations, music and what they led to

Many people's first meeting with mathematics is through recreational puzzles. Solving puzzles leads to good maths!

An early example of this is the Labyrinth in the story of the minotaur



Later became the Puzzle maze eg. Hampton Court



Solved by Euler, who developed the theory of networks to do it

Networks now vital in communications, genetics, medicine, ...

Understanding networks, combined with Matrix Theory (due to Cayley)



also forms a major part of the algorithms behind

Go



Some musical notes sound better when played together than others

The octave C to C

The notes C and G

(a perfect 5th)

The notes C and E

(a perfect 3rd)



Reason was discovered by Pythagoras



Length of strings giving C and G, and C and E, were in simple fractional proportions

C:C ... 2/1 C:G ... 3/2 C:E ... 5/4

Pythagoras invented the Just Scale .. Sequence of notes with frequencies in simple fractional proportions

1 : 9/8 : 5/4 : 4/3 : 3/2 : 5/3 : 15/8 : 2



Problem: Keyboard instruments could only be tuned for one key



Mathematicians invented a new Well Tempered scale with all notes in the same proportion

a geometric progression of the semi-tone frequencies, ratio

$$1.059.. = 2^{1/12}$$

which works well in all keys

3. Maths tells us where we are.

Big problem of the 18th Century was finding position at sea.



Sextant allowed us to find Latitude



But problem was finding Longitude.



Ephemerides calculated to give the locations of the celestial bodies.

A major mathematical achievement!

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Roots in astrology!

Additional tables were used to solved the spherical triangles encountered in the calculations

(Lie again)



Midshipmen had to 'perform a tedious 22-step mathematical calculation to plot a ship's position'

But these calculations changed the world

Babbage's difference engine



Designed to compute the Ephemerides. Ideas behind it led directly to the modern computer

4. Mathematicians save lives

Radon 1917



Studied shadows cast by objects.

Asked the question of: whether you can reconstruct the shape just by knowing the shadows?

Shadow

Object

$$\begin{aligned} R(\rho,\theta) &= \int f(\rho\cos(\theta) - s\sin(\theta), \rho\sin(\theta) + s\cos(\theta)) \ ds \\ f(x,y) &= \frac{1}{2\pi} \int e^{i\omega \cdot x} \ d\omega \int \int e^{-i(\theta - \omega)\rho} R \ d\theta d\rho \end{aligned}$$

Modern CAT (Computerised Axial Tomography) scanner implements this and related formulae to look inside you.







Also used to





X-ray mummies Detect land mines Save bees



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If you solve a Griddler puzzle or a Killer Sudoku then you are using the maths of tomography

5. Maths communicates



Error correcting codes.

Used to store the numbers 0,1,2,3,4,5,6,7 and other data in such a way that any errors can not only be detected but corrected.





They work by asking extra questions to make the answers as different as possible so we can still tell the right answer even if it has mistakes in it

They are widely used in

- CDs
- Digital TV and Radio
- Mobile phones
- Satellites

Invented in the 1940s by Hamming in the Bell Labs Using very fancy maths (Galois theory)



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And finally



This brief overview of what mathematicians have done for us is meant mainly to whet your appetite.

There many more applications of mathematics to the modern world, and the latest developments in maths are likely to lead to even newer technologies

Let's encourage our students who will lead us forward in this!

Mathematics also plays an important role in the study of

Games:

Prisoner's dilemma

Mornington Crescent







John Nash

John von Neumann

Game theory developed to solve them is now used widely in auctions and even biology