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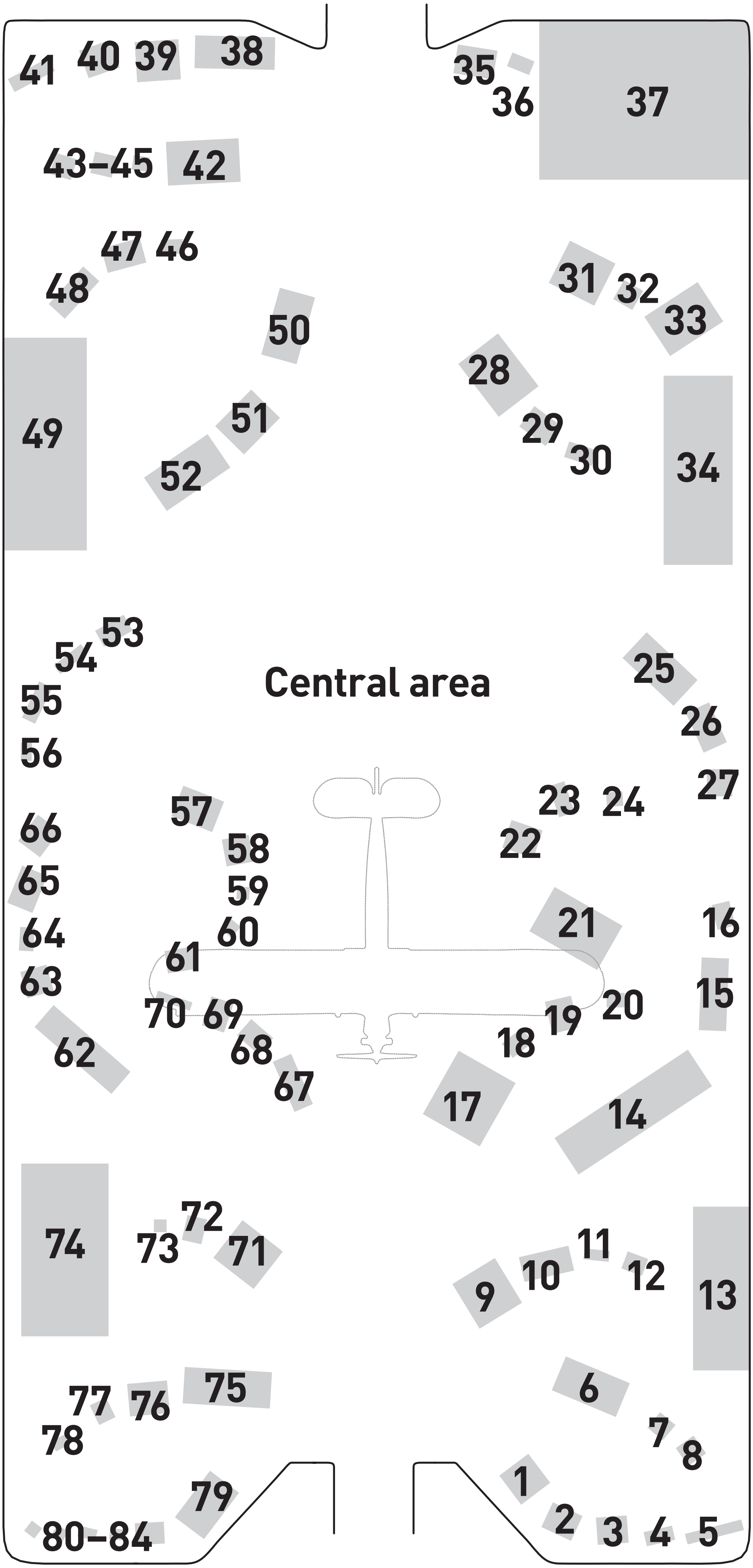
Mathematics

The Winton Gallery

Gallery plan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Mathematics
The Winton Gallery

People use mathematics in industry, commerce and government, at universities, at home and at play. Salespeople and sailors, gamblers and garden designers, coders and traders, engineers and insurance clerks, medics and the military – all may be thought of as mathematicians and all have interesting stories to tell.

This mathematical practice has shaped, and been shaped by, some of our most fundamental human concerns – money, trade, war, peace, life, death and many others. This gallery presents 21 historical stories about people and their mathematical work over the last 400 years. Together, these stories show how we have tried to understand and control the world using mathematics.

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Safe aircraft

In September 1929 the experimental aeroplane above your head took to the skies at a military air base near Manhattan. It was a competition entry based on the work of pioneering mathematicians and engineers trying to make aircraft safe.

There was a lot riding on it. People's lives and the future of aviation depended on getting aeroplane design right. The mathematics was fundamental. Making aircraft safe is just one example of how mathematical practice is vital throughout the modern world.

Central column label

Handley Page 'Gugnunc' aircraft
1929

This aeroplane was an experiment made for a 1929 competition to construct a safe aircraft. Look at the front and rear edges of its wings. The flaps and slots enabled the aeroplane to fly slowly and steeply without stalling and crashing.

A lot of research into aviation took place in universities, laboratories and factories during the First World War and the years that followed. Important work was done by women and men trained at mathematical centres such as Cambridge University and Imperial College London. Their contributions had a lasting effect on modern aviation.

Donated by: Handley Page Ltd
Object no: 1934-313

'There were no programmes, no calculating machines. We relied upon our slide rules and arithmetic in the margins. Lives were at stake and we couldn't afford to let anything go through wrong.'

Letitia Chitty, recalling work at the
Admiralty Air Department, 1917–18

Zaha Hadid Architects gallery design 2014–16

This gallery's design, by Zaha Hadid Architects, is mathematical. The curved overhead structure and the layout of the gallery represent airflow around the historic aircraft suspended at the centre.

The design was driven by equations of airflow used in the aviation industry, which are still an important area of mathematical research. Dame Zaha Hadid trained first in mathematics before studying architecture, and the work of her practice is strongly informed by ideas about geometry.

'When I was growing up in Iraq, math was an everyday part of life. We would play with math problems just as we would play with pens and paper to draw – math was like sketching.'

Dame Zaha Hadid, architect, 2014

Form and beauty

We shape the world around us to provide shelter and make statements about our status and beliefs. Mathematics has helped us do this for thousands of years.

Proportion makes for harmonious buildings. Perspective gives us a commanding view over the landscape. And without the work of mathematicians today's most daring buildings could not stay up.

Perspective

There are formal gardens all over Europe. Places such as Hampton Court and Versailles are popular with visitors keen to explore their sweeping vistas, intricately patterned flowerbeds and dramatic water features. You can see a drawing of one of these lavish gardens to your left.

Mathematics played an important practical role in their creation. It was used to carry out land surveys, establish levels, understand the behaviour of soil and create watercourses. Arithmetic was required in everything from calculating seed densities to effective cost management.

But garden designers also used mathematics to play with perspective, a technique they shared with artists. They wanted to show that the garden's owners could control nature, territory and people. Perspective was essential in creating this image, which proposed that mathematics could change the world.

Print of Herrenhausen Gardens
About 1708

This image shows the formal gardens at Herrenhausen, a district of Hanover in today's Germany. The gardens' design used a variety of mathematical techniques including intricate geometrical patterning and a deep understanding of perspective.

The mathematical use of perspective placed the gardens' visitors at the centre of the landscape. Vistas were lengthened and the human viewpoint elevated. The gardens' designers wanted to symbolise our ability to control nature for our own purposes using mathematical logic and reason.

Object no: 2016-513

Anamorphic painting of a ship
About 1750

Art, architecture and design made widespread use of the mathematics of perspective. This could make scenes appear more real or correct optical distortions. Perspective could also be used to show artistic and optical virtuosity. Without the mirror this painting looks unintelligible, but in the mirror you can see a ship. This technique is known as anamorphosis.

Other artists painted anamorphic pictures that simply needed to be viewed from a particular position. This technique was used to extend the appearance of 17th-century gardens when viewed from the house.

Donated by: George Gabb
Object no: 1948-326

Plane table and alidade
About 1800

People carrying out 18th-century surveys of landscapes, whether to make maps or design gardens, often used plane tables such as this. A piece of paper would be clamped on the top of the table. The angles to distant features, sighted through the straight brass 'alidade', could then be drawn directly without having to carry out mathematical calculations.

Some surveying specialists felt this simplification of the mathematical process meant surveyors who used plane tables had lower status. But their speed and ease of use made these instruments very popular.

Donated by: Thomas Henry Court
Object no: 1917-106

Optical balance level
18th century

Instruments such as this were used by surveyors and those laying out gardens to find the heights of distant features or to establish a horizontal level.

It consists of a lead tube suspended by a thread from the top of the wooden case so that it hangs horizontally. The surveyor would look through the window on one end of the case and adjust the instrument until sights on the ends of the tube lined up. In practice it was unreliable and was superseded by the spirit level, which is still common today.

Donated by: Thomas Henry Court
Object no: 1913-258

Lecture diagrams by J M W Turner
About 1817–28

The landscape painter J M W Turner was the Royal Academy's professor of perspective from 1807 to 1837. He made an extensive series of pencil and watercolour lecture diagrams, including these, to teach his students the mathematical techniques needed to create convincing scenes.

Perspective is a profoundly important mathematical concept in the history of art and design. Its manipulation enabled artists and designers to create objects and spaces we perceive as realistic. The boundaries between art and science have always been blurred.

Lent by: Tate Britain
Object nos: L2016-2011, L2016-2012

'Without the aid of perspective, art totters on its very foundation.'

J M W Turner, about 1810

How buildings stay up

When the National Westminster Tower, shown as a model to your right, was completed in 1981 it was the tallest building in the UK. It was an audacious statement of engineering confidence.

There is nothing new in pushing the built environment to the limits. What has changed in the last century is the significance of mathematics in designing complex structures that stay up despite the best attempts of gravity and other natural forces to bring them down.

Taller buildings. Longer bridges. Deeper tunnels. Bigger ships. Space technology that can take us to the stars. These are the dreams of humanity – to take control of nature and to reshape the world in new and more daring ways. And these dreams have been realised by slide rules and equations.

Model of the National Westminster Tower
Completed 1981

The 42 storeys of the National Westminster Tower (now Tower 42) hang over visitors' heads as they enter. Instead of columns, the floors sit on three huge slabs embedded in the central core, appearing to float. This was only possible by painstaking mathematical analysis. The problem was so complicated the engineers initially ran out of computer space to solve the equations.

It is mechanical tricks such as these which enable engineers and architects to build taller, slimmer and more daring buildings, resisting gravity, wind and earthquakes intent on destroying them.

Find out more on the touch screen nearby.

Lent by: RIBA Collections
Object no: L2015-4304

String model of a vaulted roof form
1872

Mathematical training for engineers and builders increased rapidly in the Victorian age, as structures became better understood. This is one of a set of models showing that curved forms in architecture, such as roof vaults, could be constructed from straight elements, represented here by strings. Such models were eagerly acquired by engineering schools keen to teach the latest techniques.

Impressive architectural forms were symbols of progress and modernity. Complicated geometrical structures were easier to build with mathematical knowledge, and mathematical instruments became a vital part of every engineer's toolkit.

Object no: 1872-129

Image: Montsouris Reservoir, built in Paris in the 1870s. With its vaulted roof it was a spectacular symbol of progress and modernity.

Courtesy of Cnum – Conservatoire Numérique des Arts et Métiers

Calculator for reinforced concrete 1920s

This is a multipurpose slide rule made for engineers working with reinforced concrete, first used in earnest as a building material in the 1890s. Rules of thumb were no good for this challenging new construction material, in which much of a building's strength – in the steel reinforcing bars – was hidden once the concrete was poured. A mathematical approach was needed to ensure concrete buildings stayed up.

As 'The Times' remarked in 1909, concrete construction could only be successfully carried out by 'engineers possessing both practical and mathematical knowledge', although the formulas were 'perhaps rather terrifying at first sight'.

Object no: 1990-4594

Proportion

Why do some buildings, products or pieces of furniture look right? What rules should be followed to make things appear harmonious or beautiful, like nature? For at least 2500 years people have believed the answer lies in mathematics.

Greek architects were the first to develop mathematical rules of proportion for designing structures. At a practical level these rules made it easier to design and construct buildings. They offered a governing logic and a standard unit of measurement for layouts, room dimensions and façades. But the rules also expressed ideas about beauty, reflecting proportions found in nature.

These classical ideas, developed further by Roman architects such as Vitruvius, were given new life by Renaissance scholars from the 15th century onwards. Together these architects created a mathematical language of design that still surrounds us.

LC1 chair by Cassina
2015

The type of chair displayed here was designed by Charlotte Perriand for the architect Le Corbusier in the late 1920s. Le Corbusier spent his career advancing the idea that all manufactured products, including buildings and their contents, should be designed to mathematical rules of proportion.

Le Corbusier, a pioneer of modern architecture, believed that these rules, which created harmony with the human form, would lead to beautiful structures, whether chairs or buildings. He was developing ideas first explored by Greek and Roman architects which were revived in the Renaissance from the 15th century onwards.

Object no: 2015-486

‘Charlotte Perriand creates interiors as an urban planner, distinguishing among a house’s functions, and she does this while always providing beautiful proportions.’

José Luis Sert, architect and collaborator with Le Corbusier, 1956

Image: ‘Le Modulor’, a system of proportions based on the human body developed by the architect Le Corbusier in the 1940s.

Architect's set of drawing instruments
About 1800

This extensive set of mathematical instruments was assembled in about 1800 for use by an architect. It includes instruments for measuring and drawing lines and angles with great precision, among many other uses. Most architects used much more modest sets to design their buildings.

Architecture has had a close relationship with mathematics for at least 2500 years. Architects from the ancient world onwards have believed that rigorous mathematical rules lead to beautifully proportioned buildings in harmony with nature. Modern architects are still sensitive to the effects of proportion.

Object no: 1952-232

Image: An architectural drawing class, early 20th century, showing students using mathematical instruments.

Private Collection/Calmann & King Ltd/ Bridgeman Images

Architectonic sector by George Adams
About 1770

This is a specialist mathematical instrument for architectural drawing. It enabled scale measurements to be made for all sorts of architectural features, including columns, pedestals, doors, arches and column fluting. These measurements could be read off directly without having to be calculated.

The inscriptions on the curved plate show the variety of features that could be drawn using this instrument. The straight arms, where they join the curved plate, contain the legend ‘TDJCR’. This stands for ‘Tuscan’, ‘Doric’, ‘Ionic’, ‘Corinthian’ and ‘Roman’ – five ancient architectural ‘orders’, each with its own proportions.

Object no: 1927-1010

‘De Architectura’, by Vitruvius
About 15 BC (1543 edition)

We know about ancient rules of architectural proportion through the writings of the Roman architect Vitruvius. His book on the subject, written over 2000 years ago, is the only original source known to have survived. When a copy was discovered in the 15th century it had a profound effect on architecture that we can still see today.

Vitruvius described a belief that buildings should be designed according to a fixed set of mathematical rules of proportion. By using these rules architects would ensure human-made structures were in harmony with natural ones, with mathematics providing the link.

Source: Science Museum Library

‘Let him be educated, skilful with the pencil, instructed in geometry, know much history, have followed the philosophers with attention, understand music, have some knowledge of medicine, know the opinions of the jurists, and be acquainted with astronomy and the theory of the heavens.’

Vitruvius, discussing architectural education,
about 15 BC

Door case from 56 Lincoln's Inn Fields, London About 1750

This wooden door case was salvaged from an 18th-century building in central London, demolished in 1912. The columns, and the triangular pediment they support, follow a set of mathematical rules of proportion first described over 2000 years ago.

The door surround was added to an otherwise plain house to give it higher status, suggesting the occupant was a gentleman with a classical education. We still add classical features to otherwise unremarkable buildings today because classical architecture has a strong hold on British imagination and culture.

Lent by: English Heritage Architectural Study Collection
Object no: L2016-2003

Image: Door case from 56 Lincoln's Inn Fields pictured in situ, May 1906. The house was demolished six years later.

Courtesy of London Metropolitan Archives (www.cityoflondon.gov.uk/lma)

Trade and travel

The modern global economy is based on our ability to trade with other countries, ship vast quantities of goods, and travel readily around the world.

Mathematics has underpinned this activity for centuries, whether helping us navigate safely, design efficient ships, communicate in private or transact goods fairly.

The shape of ships

It is easy to forget the importance of modern shipping in our daily existence. Yet without oil, coal, iron ore, grain, fertilisers and metal containers full of consumer products, all carried around the world by 50,000 ships, our lives would be very different.

Modern super-ships, such as the oil tanker 'Globtik Tokyo' (shown as a model to your left), are carefully designed to reduce fuel consumption. They have to be, because each one runs on a knife edge of profitability. Commercial success depends on keeping ship fuel costs down.

That, in turn, relies on the 19th-century studies of mathematician turned engineer William Froude, who developed novel techniques for designing low-resistance ships. He combined mathematical theory with practical experiment to set the foundations for modern studies of water flow around vessels.

Model oil tanker 'Globtik Tokyo' 1973

'Globtik Tokyo' was one of a new breed of ultra-large tankers designed to transport 500 million litres of crude oil from the Persian Gulf to Japan. When completed in 1973, 'Globtik Tokyo' was the largest ship in the world. This model was made by the ship's builders.

The global economy relies on ships being able to operate cheaply. The shape of the ship's hull is crucial in keeping fuel costs down. Experiments by mathematicians and engineers in the 1860s showed that a bulbous bow at the front of the ship gave less resistance at high speeds than the sharp bows favoured for large ships at the time.

Donated by: Ravi Tikkoo
Object no: 2006-30

Image: Oil tanker 'Globtik Tokyo' being readied for launch in Kure, Japan, watched by shipyard workers and their families, 1972.

‘Raven’ and ‘Swan’ hull models
1867

Mathematicians had worked out theoretical equations of water flow around ship hulls by the 1840s. However, they were often difficult to solve in practical situations. William Froude, a mathematician turned engineer, experimented with these scale models to see which shape offered less resistance.

Froude developed mathematical relationships showing how model behaviour scaled up to full-sized vessels. This enabled him to show that a bulbous front, or ‘bow’, was better on large ships at high speeds than a sharp bow, contradicting leading shipbuilders such as John Scott Russell.

Donated by: Board of Admiralty
Object nos: 1941-4/1, 1941-4/2

‘You will have on the small scale a series of beautiful, interesting little experiments, which I am sure will afford Mr Froude infinite pleasure in making them, but which are quite remote from any practical results upon the large scale.’

John Scott Russell, April 1870

Slide rule designed by William Froude
1877

This circular slide rule was designed and used by the ship design expert William Froude to speed up calculations. It was manufactured by the prominent mathematical instrument-makers Troughton & Simms.

Froude spent the 1870s carrying out a series of experiments on ship design using the world's first ship test tank, built by the Admiralty near his house in Torquay. He used the slide rule to relate the results from these experiments to mathematical theory.

Donated by: Board of Admiralty
Object no: 1941-8/1

Codes and secrets

When you put your bank card into an ATM to withdraw cash, your account details are not held on the machine itself. The ATM has to ask your bank's central computer whether you have enough funds to meet the request.

To do this it has to communicate over a long-distance telephone line. Anybody could listen in and steal your data – then your money. This was the problem facing computer giant IBM in the 1970s, when it was developing early ATM networks.

The answer lay in mathematics, which was used to encrypt the information flowing over the network, keeping it secret. IBM's in-house system became a global standard for data encryption. Today, mathematics is at the heart of all computer security – as well as attempts to break it.

IBM automated teller machine (ATM)
1987

On-street cash machines need to retrieve account details from a bank's central database without them being captured by criminals eavesdropping on the phone lines. In 1973 computer giant IBM developed a powerful mathematical encryption method for its early ATM networks.

When the US government wanted an encryption system to protect a wide range of civilian computer networks, it used a modified version of IBM's system which became known as DES, or Data Encryption Standard. This became a global standard for data security for over two decades. The ATM on show uses DES.

Find out more on the touch screen nearby.

Object no: 1995-423

Encryption device for secret communication
About 1780

People have been using mathematical techniques to send secrets across unsecure networks for hundreds of years. This is an 18th-century example of a device for encrypting and decrypting messages that could be sent by post.

Moving the sliding bars substitutes numbers for the letters in the original message, to make up the encrypted message. This looks simple, but the mathematical technique it uses, known as a polyalphabetic cipher, was the basis of 20th-century encryption machines such as Enigmas.

Object no: 1991-372

'Peculiar invention for correspondence, for something very confidential between friends, or for ministers, or for ambassadors.'

Translation of the written instructions

Enigma machine
1934

Probably the most famous encryption system is the Enigma machine. This is an early example. Enigma machines were electromechanical devices designed to resist advanced mathematical techniques for code-breaking.

Enigmas were originally made for business use, but were taken on by the German military and used extensively in the Second World War. Mathematicians in Poland, France and the UK developed advanced techniques that broke the Enigma code, helping shorten the war.

Find out more on the touch screen nearby.

Donated by: Government Communications Headquarters
Object no: 1980-1200

Quantum computing chip
2012

Most cybersecurity systems could be broken easily if computers were fast enough to carry out the huge number of repetitive mathematical calculations needed to crack the codes. With today's technology these calculations take too long to be practical.

But physicists working with a technique known as quantum entanglement are developing new types of computer. If perfected and scaled up, these could slash the calculation time from years to seconds, leaving existing data-encryption methods worthless. This is a quantum computer chip from recent experiments in this field.

Lent by: Centre for Quantum Photonics,
Bristol University
Object no: L2015-4445

Navigation

The greatest scientific and commercial problem of the 17th and 18th centuries was navigational – known as the longitude problem. Thousands of lives and millions of tonnes of cargoes were lost as ships were wrecked or ran out of supplies because of navigation errors.

The model to your right represents an East Indiaman, a merchant ship carrying valuable goods thousands of miles across treacherous oceans. One solution to the problem of navigation lay in the Moon and stars – and in mathematics. In a pioneering state-sponsored science project, a technique known as lunar distances was developed.

Mathematics is at the heart of finding our position. New technologies such as satellite navigation make the job easier. But by relying on machines, we risk losing centuries of practice in navigating from basic mathematical principles.

Instruments for lunar-distance navigation 1790s

Marine sextant, about 1790
Donated by: Meteorological Office
Object no: 1974-619

Pocket chronometer, about 1795
Donated by: Edwin Earnshaw
Object no: 1915-408

'Nautical Almanac', 1790
Source: Science Museum Library

Model of an East Indiaman, about 1809
Object no: 1929-406

The 16th and 17th centuries saw an explosion in British trade with overseas nations. The East India Company, founded in 1600, came to dominate Britain's imports and exports. It was so successful it chartered a huge fleet of ships (known as East Indiamen) that could rival any navy.

The company eagerly took on new navigational techniques. One was known as lunar distances, first introduced in the 1760s. Navigating officers, trained in mathematics from a young age, used scientific instruments and tables of numbers to find their position. But this involved mind-numbing mathematical calculations that could take hours.

Find out more on the screen nearby.

Image: Navigating officer using a sextant to measure the Moon's position against the stars.

Science Museum/Science & Society Picture Library

Coastal navigator
About 1887

Ocean-going ships navigated using the mathematical method known as lunar distances alongside other techniques. But many ships never reached the open sea. It was often easier to send goods from one town to another by ship, travelling around the coast, than by horse and cart on poor roads. Coastal sailors developed mathematical tools for navigation too.

This angle-measuring device allowed navigators to use coastal landmarks to plot a ship's position accurately without a direction-finding compass. Coastal sailors could therefore avoid treacherous rocks or reefs, although the device was a commercial flop.

Object no: 1985-1810

'Many useful problems in navigation can be readily worked by this instrument; it is also applicable for solving problems in oblique angled trigonometry and is a most valuable instrument for the coast navigator and nautical surveyor.'

Norwood Harrison, inventor of the coastal navigator, 1887

Aircraft navigator's 'computor'
About 1940

Navigation is one of the oldest mathematical practices, relying on an understanding of geometry and angles. The practice expanded rapidly in the 20th century when aircraft took to the skies, where officers had to navigate more rapidly and cope with varying wind speed.

New technologies such as radio location were developed, but navigators still needed a strong command of mathematics. Tools such as this 'computor', with its slide rules and graphs, helped officers calculate aircraft speed, height and distance while sitting in their cramped aircraft cabins.

Object no: 1990-704

Global positioning system (GPS) receiver
1993

Navigation remains a mathematical practice, although the technologies change over time. Today, GPS satellites orbiting the Earth broadcast time signals from on-board clocks. Our GPS receivers calculate our position by measuring tiny time differences between the signals. This is done using a technique known as trilateration, involving the geometry of circles and triangles.

However, GPS signals are weak and can be deliberately jammed. Some navigation specialists worry that people will have lost the ability to navigate if the system fails. Older methods are being reintroduced as backups.

Donated by: Rockwell Collins UK Ltd
Object no: 2014-412

Weights and measures

Measurement is at the heart of trade. Yet two centuries ago there was no international standard of weight. Each region had its own local standards. For trade to flourish, merchants needed to know how foreign weights compared with British ones. This information was published in conversion tables, but nobody had calculated them precisely enough.

In 1818, the government set out to solve this problem. Overseas consuls were instructed to send sets of local weights to London. The cabinet to your right held them together at the Royal Mint, near the Tower of London.

In 1820, the mathematician Patrick Kelly and Robert Bingley, the king's assay master, carefully compared each set of weights with Britain's standard weight. The results showed that the old conversion tables had often been wrong.

Cabinet of foreign weights
1818–20

This cabinet was held at the Royal Mint, London, from 1818. It housed weights collected by British consuls stationed overseas, each drawer containing standard weights from the place marked on the front. Each set of weights was then carefully compared with the British standard.

The situation was complicated, though. Take Rome. If you were a merchant buying gold and silver you needed one set of weights. Medicines required another. Commercial goods involved a third. Dry goods such as salt had their own measures. But after all the weights had been compared, merchants could finally refer to accurate conversion rates for each product.

Donated by: Board of Trade
Object nos: 1932-193 – 1932-245

‘To the British consuls abroad: you will use your endeavour to procure the standard pound or mark used at your place of residence for weighing gold and silver, and also of other lesser weights used for that purpose.’

Viscount Castlereagh, Foreign Secretary,
10 March 1818

Elizabethan weights and measures 1588–1601

These are standard measures for volume, weight and length, made on the instruction of Queen Elizabeth I between 1588 and 1601. Elizabeth's standards were sent to 60 English cities so that – for the first time – all merchants could share the same definition of measurement units.

The queen had recognised that a common set of measurement standards across the country was crucial to commercial expansion, and her reform of Britain's system of weights, measures and currency was wide-ranging.

Donated by: Board of Trade
Object nos: 1931-947, 1931-985, 1931-1017, 1931-1018, 1931-1019

Council inspector's testing weights
1890

Local authorities need a way to check that shops are not short-changing their customers. This case of testing weights was used by London County Council officials who carried out inspections on shops and market stalls.

Inspectors would call on shopkeepers unannounced to test their weighing scales. Any machines found to be showing short measures would be seized. Up to 30,000 sets of scales were tested in London each year. This work still goes on today.

Donated by: London Borough of Southwark
Object no: 2000-1421

Image: London County Council inspectors testing scales during a raid on a London shop, about 1939.

Courtesy of London Metropolitan Archives
(www.cityoflondon.gov.uk/lma)

War and peace

The urgent demands of war can bring about mathematical innovations which find new uses in peacetime. Alternatively, peacetime mathematical research can find applications in the military.

From bomb production and artificial intelligence, to making difficult decisions in a hurry, there has always been an intimate relationship between mathematics, war and peace.

Recognising patterns

In 1950, Alan Turing, now famed for code-breaking during the Second World War, asked the question 'Can machines think?' Three decades later, the machine to your left debuted on national television. It seemed the answer might soon be 'yes'.

A critical sign of intelligence is recognising patterns. The machine had first been trained with pictures of its creators' faces. Then, one after another, the scientists sat in front of a live camera linked to the machine. It had to decide whether any of the faces it saw matched the face patterns stored in its memory.

It recognised them all, calling out each scientist's name. Then a scientist new to the machine walked in. 'INTRUDER! INTRUDER!' it shouted. 'The computer immediately spots the odd man out,' the television presenter said. 'The security implications are obvious.'

Wisard pattern-recognition machine
1981

The human brain is a complicated maze of neurological connections. So what would you do if you wanted to make an artificial brain? You might build a machine that mimicked the way the human brain works. One result is a neural network, and this is one of the first ever made. It looked for patterns in data.

How likely was it that a face seen in a camera matched face patterns stored in the machine's memory? Artificial neural networks learn from their surroundings using the mathematics of probability.

Find out more on the touch screen nearby.

Donated by: Brunel University
Object no: 2002-297

'Reading is no problem at all. It's extracting meaning from what's being read that is difficult.'

Igor Aleksander, co-inventor of Wisard, 1983

Electrical logic machine
1949

Pattern recognition was part of wider research into machine intelligence. This machine was made by physicist Dietrich Prinz, one of Alan Turing's protégés, and Wolfe Mays, a philosophy lecturer. It is an electrical device for testing certain logical statements and helped researchers build human-like qualities into machines using mathematics.

Research into pattern recognition now has widespread commercial and military applications, from driverless cars, fingerprint scanners and robots on battlefields, to surveillance and cybersecurity. Mathematicians work throughout this field.

Lent by: Manchester University
Object no: 1959-25

Image: Dietrich Prinz programming a chess game into a digital computer, 1955.

‘Logical demonstrator’
About 1805

Machines that imitate the human mind have long been a dream of humankind. In the 19th century some people started turning the dream into reality, building mathematical language into machines that tested whether statements were logically correct.

One of the first was the statesman and mathematician Charles Stanhope, who constructed a set of ‘logical demonstrators’, including this one. Logic machines became expressions of a mathematical world view, which searched for patterns in the complex world around us. Today, this has countless potential applications in industry and the military.

Donated by: The Earl of Stanhope
Object no: 1953-353

Peacetime payoff

In 1937 huge radar masts began to appear at sites up and down Britain's coast, forming a line of defence against enemy aircraft as Europe was gearing up for war. In theory, radar was a powerful defence against German bomber aircraft. In practice, the system was highly complex.

The efficient operation of a radar network depended on many complicated factors. So military commanders asked mathematicians to develop new ways to make decisions on network design, as well as to solve wider military problems such as bombing strategies.

Their techniques – known as operational research – used mathematics to analyse large amounts of data. Operational research was widely used after the war ended, in fields as diverse as biology, commercial logistics and farming. New computing technologies increased its power.

Model radar masts
1938–40

These models show masts used to house transmitters in Britain's first coastal radar system. Radar worked by bouncing radio signals off approaching enemy aircraft, giving time to sound warnings and scramble British fighter aircraft.

The location of masts, the effects of weather, radio interference, enemy jamming – these and a host of other complicating factors made the job of operating the radar network immensely hard. But mathematicians developed an answer. Their statistical method of making quick decisions in a hi-tech military campaign changed the course of the Second World War. After the war it transformed peacetime science and commerce too.

Donated by: Defence Science and Technology Laboratory
Object nos: 1962-365/1, 1962-365/2

Image: Radar station, Dorset, about 1941.

‘The essence of research in war is to be ahead of the enemy. Operational research involves new, untried equipment which is going through its teething troubles and which has to be tried out under war-like conditions.’

Archibald Hill, operational research pioneer, 1941

Model myoglobin molecule
1957

In 1957 the molecular biologist John Kendrew made this model describing the structure of the protein myoglobin. Each of its plates showed a 'slice' of the protein, calculated from countless X-ray measurements. Looking down through the stack offered a glimpse of the three-dimensional structure of the molecule.

This research involved vast amounts of measurement and computation. To help make sense of it, Kendrew used the mathematical technique known as operational research, which he had helped develop during the Second World War. This was useful in problems with lots of data that was often incomplete.

Donated by: Henry C Watson
Object no: 1977-180

Image: Punched data strips used in mapping myoglobin being carried between buildings at Cambridge University, 1959.

Courtesy of Bror Strandberg, Richard E Dickerson and the MRC Laboratory of Molecular Biology, Cambridge

Ferranti Atlas computer console
About 1964

Ferranti Atlases were the most powerful computers in the world when first released in 1962. This is the console from the University of London's machine. The computer itself occupied two large rooms.

The university's Atlas was partly funded by British Petroleum, which used it to calculate routes for its oil tanker fleet. The problem of finding the shortest route involved great complexity. There are millions of different routes one tanker can take to visit just a handful of different ports. Mathematical techniques developed during the Second World War made the problem manageable.

Donated by: London University Computing Centre
Object no: 1973-563

Elliott 401 computer
1954

This computer was used for 11 years at the Rothamsted Agricultural Institute for everything from analysis of crop trials and insect damage, to work in the mathematics of genetics. It was brought there by Frank Yates, a wartime operational researcher who established Rothamsted as a peacetime statistical computing centre.

Rothamsted had developed as a pioneering site for statistical research under Ronald Fisher. Fisher laid the foundation for much of modern statistical theory, including the randomisation crucial in clinical and agricultural trials today. Yates himself tirelessly encouraged the use of statistical analysis in government research.

Donated by: National Research Development Corporation
Object no: 1965-445

Image: Part of the Elliott 401 computer being installed at Rothamsted in 1954.

Courtesy of Rothamsted Research

‘Many outstanding statisticians came to Rothamsted for short periods under Yates, and went on to high positions in university departments of statistics.’

Frank Yates obituary, 1995

Solving equations

In the 1920s electrical engineers had a problem. They were working on bold projects to knit together local electric power networks and form long-distance grids of wires and transmission pylons. But the mathematics of how electricity travelled across large interconnected networks was a huge challenge.

The ebbs and flows of power, second by second, could be described by differential equations, which are very common in engineering. These mathematical equations were part of calculus, the study of change, first described in the 17th century by Isaac Newton and Gottfried Leibniz.

But solutions to the equations were often time-consuming to calculate. So in the 1930s machines known as differential analysers were built that could solve them much more quickly. These later saw widespread military use.

Model electricity transmission pylon
About 1951

This model shows an electricity pylon, or transmission tower, part of a power grid that was installed across Britain from the late 1920s onwards. Similar towers served power grids across Europe and America.

The dynamic nature of electricity flow across these new long-distance grids needed to be carefully understood. What would happen when lightning struck the grid, or a power station was switched on, or a thousand factories started up for the day? The resulting power spikes needed to be modelled using mathematical equations.

Donated by: BICC plc
Object no: 1957-161/2

'The solution of these equations is often difficult, and the kind of arithmetical work involved is not well known, and is prolonged and wearisome.'

'The Meccano Magazine', 1934

‘The Method of Fluxions and Infinite Series’, by Isaac Newton 1736

This book was written by the mathematician and natural philosopher Isaac Newton in the late 1660s, although it was not published until 1736. Newton wanted to create a mathematical language to describe physical quantities that are constantly changing.

These situations can be described by differential equations, and occur widely in everything from bombs and astronomy to electricity and economics. While today this mathematics is known as differential calculus, Newton used the term ‘fluxions’. Calculus is a vital mathematical tool.

Source: Science Museum Library

Plinth (37)

Differential analyser
1935

This machine, known as a differential analyser, was built in 1935 to help Manchester University physicists solve problems in a variety of fields ranging from electrical power transmission to bomb production.

During the Second World War this machine was put to use in military research. One secret project involved calculating the mathematics of uranium enrichment, vital in manufacturing the atomic bomb dropped on the Japanese city of Hiroshima.

Find out more on the touch screen nearby.

Lent by: Manchester University
Object no: 1974-597

Image: Mathematicians Kathleen McNulty, Elizabeth Snyder and Sis Stump operating a differential analyser at the University of Pennsylvania, about 1943–45.

Courtesy of University of Pennsylvania

‘At one point, there were about 100 women on two shifts, with those on the incoming shift continuing work on the incomplete trajectory computations from the previous shift until each trajectory was completed.’

Kathleen McNulty, recalling bomb trajectory work on a differential analyser in 1943–45

Maps and models

We live in a world whose size and forces threaten to overwhelm us – vast continents, perilous oceans, the infinite expanse of space.

We use mathematics to try to bring the world to order. This involves making maps and models, physical and virtual, so we can explore, understand and control our surroundings.

The power of computers

It is hard to imagine a world without computers. We have lived with the modern electronic digital versions since the late 1940s, and with special-purpose computing devices for far longer.

The power of today's computers is the way they can compute anything we can express in numbers. At their heart, computers are just fast calculators performing simple mathematical operations on the numerical digits 'one' and 'zero'. But those ones and zeros can stand for other things in the software – they can be symbolic.

This fundamental conceptual leap was made by the mathematician Ada Lovelace when studying designs for the machine to your left, which is a small trial assembly for what would have been a gigantic Victorian mechanical computer. Today computer software can model just about anything.

Analytical engine trial model
1834–71

The assembly shown here is one of the only parts of Charles Babbage's analytical engine that he completed. It was intended to be a high-powered mathematical calculator. But it went much further. Calculators gain enormous power if the numbers they manipulate are symbolic of other things. This conceptual leap was made by Ada Lovelace while studying Babbage's invention.

In 1843 Lovelace explained that the engine 'might act upon other things besides number'. It might, for example, express musical notes as numbers. She suggested that 'mathematical truth' was the 'instrument through which the weak mind of man can most effectually read his Creator's works'.

Donated by: Major-General Babbage
Object no: 1878-3

'We are not aware that anything in the nature of the Analytical Engine has been hitherto proposed, or even thought of, as a practical possibility, any more than the idea of a thinking or of a reasoning machine.'

Ada Lovelace, mathematician, 1843

Calculating machine
About 1939

This office calculating machine was used at the Scientific Computing Service (SCS) from about 1939 to 1965. The SCS, founded in 1937, employed mathematically trained women using machines such as this to solve a wide range of practical mathematical problems.

The company acted like a human version of modern general-purpose computers. Complicated problems were broken down into many smaller calculations, each carried out by different employees. This meant that solutions could be found more quickly than if only one person worked on the problem.

Donated by: University College London
Object no: 1981-391

Image: Beryl Waters, SCS mathematician, studying drawings of a calculating machine, 1942.

'During the early part of the war, map projections and military grids involving tremendous and exact calculations were needed as quickly as we could produce them. Those office machines enabled us to do the work in very quick time.'

Leslie Comrie, founder of the SCS, 1942

PDP-8 minicomputer
1965

The first digital computers were huge, occupying entire rooms. The PDP-8 was the first successful minicomputer, a computer small enough to fit into offices and laboratories. It was widely used in engineering, science and medicine.

At their heart, computers like this are just fast calculators. Their power comes from the fact that the numbers they manipulate can represent other things. Numbers are symbolic, so computer software can be used to model and test virtually anything we choose. The faster the hardware can crunch the numbers, the more powerful the technique.

Donated by: Digital Equipment Corporation
Object no: 1982-960

‘In the very near future computers will be considered as natural as desk calculating machines. What happens when a group of people become familiar with the power of computers is something which they themselves find difficult to imagine beforehand.’

‘The Times’, 25 May 1964

Mathematical software
1980s–90s

MATLAB 1.3, by MathWorks, 1985
Lent by: MathWorks
Object nos: L2015-4493, L2015-4494

Mathematica 1.0, by Wolfram Research, 1988
Donated by: Wolfram Research
Object nos: 2016-8, 2016-9

Maple 5.0, by Maplesoft, 1997
Donated by: Maplesoft
Object nos: 2015-484, 2015-485

Today, people using mathematics in their work have access not only to incredibly powerful computing technologies, but to software which enables the most abstract ideas to be modelled and manipulated.

The first digital computers required specialist skill and expertise to program. Nowadays, software packages such as those shown here allow mathematical practitioners in all walks of life to grapple with the toughest mathematical ideas, whether modelling an aeroplane wing or testing an abstract mathematical problem.

Find out more on the touch screen nearby.

‘A new, a vast, and a powerful language is developed for the future use of analysis.’

Ada Lovelace, mathematician, on the potential of computing machines, 1843

Surveying the land

In 1828 the surveying theodolite shown to your right was brought to a remote and inhospitable spot on the shores of Ireland's Lough Foyle, a 15-mile-long estuary on the island's northern coastline. On site to receive it were 70 surveyors from the British Army who were measuring the baseline for the first Survey of Ireland, a project to map the country in fine detail.

Once the survey was completed, for the first time Westminster had access to accurate maps of land ownership in the remotest reaches of Ireland – and could get on with levying taxes.

Land surveying is one of the oldest mathematical practices, sharing features with navigation, gunnery and civil engineering. The mathematics involves measuring triangles. The results could mean the rise or fall of governments – or even empires.

Theodolite from the Survey of Ireland
1826

Theodolites are used to measure vertical and horizontal angles. Together with accurate measurements of short distances, surveyors could use the mathematics of triangles to measure much longer distances and plot geographical features across entire countries. This practice is known as triangulation.

This theodolite was used by Britain’s government in its first accurate survey of Ireland, enabling Irish farmers to be taxed on their land use. Britain had long used surveys to assert authority as its empire grew. Early military surveys attempted to bring Scottish clans under government control and in 1802 a huge survey of India was begun.

Donated by: Ordnance Survey
Object no: 1876-1204

Image: Measuring equipment being set up under protective tents to measure the eight-mile baseline of the Survey of Ireland, 1827–28.

Courtesy of Syndics of Cambridge University Library

Surveyor's angle-measuring instrument
1663

Early surveyors used instruments such as this to measure angles between one point and another. Surveying is all about triangles. Whatever is being surveyed – a building site, battlefield or entire country – the surveyor is building up a series of measurements of angles and lengths in triangles.

First, a short but accurate baseline is measured along flat ground. Then, angles between the baseline and a distant point are measured. Finally, using the mathematics of triangles, known as trigonometry, the distance to the faraway point can be calculated. This is repeated to build up a complete survey.

Object no: 1894-106

Trigonometry instrument
1664

This machine was used to simplify calculations involving triangles, using a mathematical technique known as trigonometry. Surveyors rely extensively on this practice as it enables huge areas to be surveyed using the lengths and angles of triangles.

The operator used the machine by 'drawing' the problem on it. It contained three rules which could be moved using dials to make a triangle of the required size. Angles or lengths could then be read off directly. However, it was expensive and did not catch on.

Donated by: Lt Col. H P Babbage
Object no: 1872-136

‘Total station’ theodolite
About 1979

Theodolites are widely used in surveying today, whether in large-scale map-making, by armed forces in hostile territory, or on building sites and civil engineering projects. Modern ‘total station’ theodolites measure distances as well as angles, and contain built-in recording devices for the results.

Surveying remains a specialised and vital mathematical practice. Technologies such as satellites and laser ranging offer powerful new opportunities to increase the speed and precision of surveys.

Donated by: Wild Heerbrugg (UK) Ltd
Object no: 1990-49/1

Image: An engineer carrying out survey work for a new railway, London, 2012.

Understanding the heavens

Have you ever gazed into the night sky and wondered about our place in the universe? We have been trying to understand the heavens since the beginning of time, searching for patterns in the circling stars and wandering planets.

Geometry can be used to study space mathematically. It allows us to map the heavens and construct remarkable miniature universes we can hold in our hands.

One such miniature universe was the astrolabe. The example to your left was made in 1666, but similar ones had been made for hundreds of years before that. It was a representation of the night sky, flattened into two dimensions using an ancient mathematical technique known today as stereographic projection. Astrolabes were, in effect, astronomical computers.

Astrolabe by Jamal al-Din ibn Muqim, Lahore 1666

Astrolabes were first developed by Greek and Roman astronomers over 2000 years ago. When these civilisations died out in about AD 500–600, their knowledge was largely lost in Europe, but was taken up and greatly developed by Islamic scholars.

It was said that holding an astrolabe meant holding the secrets of the universe in one's hand. Constructing the instruments relied on extensive knowledge of mathematical techniques. Makers such as Jamal al-Din, from the fourth generation of a prolific astrolabe-making family, were held in high esteem in Islamic societies.

Find out more on the screen nearby.

Object no: 1985-2077

'In the entire history of scientific instrumentation in the Middle Ages there has been no family comparable to this one.'

Sreeramula Sarma, historian, on the al-Din family of astrolabe-makers, 1994

Astronomical clock by Samuel Watson, London About 1695

Astronomical clocks were miniature clockwork universes showing the movement of the Moon and stars as well as the Sun, which gave the time of day. They were based on detailed mathematical understanding of the geometry of star and planetary motion.

Like astrolabes, such as the one shown to your right, astronomical clocks were highly prized. This one was made by Samuel Watson, a clockmaker who called himself 'mathematician-in-ordinary' to King Charles II. It is reputed to have been made for the mathematician Isaac Newton.

Object no: 1970-25

'The machinery of the heavens is not like a divine animal but like a clock.'

Johannes Kepler, astronomer, 1605

Teaching geometry 1570–1910

‘Elements of Geometry’, by Euclid, first English translation, 1570
Source: Science Museum Library

Geometry teaching models, about 1800
Object no: 2005-731

Non-Euclidean geometry models, about 1910
Donated by: University of Edinburgh
Object nos: 2006-80, 2006-86

Without geometry we could not understand the heavens. The basic elements of geometry were drawn together by the Greek mathematician Euclid in about 300 BC. Euclid’s work, which was the basis for over 2000 years of mathematics teaching, was first translated into English in 1570 by Henry Billingsley.

In the 19th century some mathematicians began expanding the use of geometry to explore abstract concepts. The larger models displayed here show ideas from this particular type of ‘non-Euclidean’ geometry, which has become a powerful theoretical tool in mathematics today.

‘Without the diligent study of Euclid’s “Elements”, it is impossible to attain unto the perfect knowledge of geometry, and consequently of any of the other mathematical sciences.’

Henry Billingsley, 1570

Astronomical telescope and regulator clock 1829–32

Telescope by Richard Sheepshanks, 1829
Donated by: Board of Admiralty
Object no: 1929-949

Regulator clock by Benjamin Lewis Vulliamy, 1832
Donated by: Lady Riddell
Object no: 1935-44

For over a decade the astronomer William Smyth laboured beneath the eyepiece of this telescope, obsessively surveying and cataloguing the stars in the sky above his house in Bedford. In 1844 he published his observations in a huge book known as the 'Bedford Catalogue'.

It has been said that Smyth was 'addicted to observations'. His catalogue, the first guidebook to the heavens for amateur stargazers, was hugely popular throughout the 19th century. Later, this clock was used alongside the telescope to make further maps of the night sky.

Image: William Smyth making an astronomical observation using the telescope on display, about 1860.

Science Museum/Science & Society Picture Library

'All the perceptible universe is amenable to the operation of time and space, motion and force, in similar relations with our own, and equally open to mathematical disquisition.'

William Smyth, astronomer, 1844

Modelling the oceans

On the night of Saturday 31 January 1953, the UK, Netherlands and Belgium suffered one of their worst floods in modern times. A lethal combination of high tides and a wind storm over the North Sea caused a storm surge which overwhelmed coastal defences, killing more than 2500 people and leaving tens of thousands homeless.

In an emotional statement to parliament the following Tuesday, Prime Minister Winston Churchill described the flooding as a 'shocking and tragic disaster'. He pledged immediate action to deal with the emergency and its aftermath.

One outcome was a huge increase in funding for mathematical research into the oceans. The electronic North Sea model on your right was one approach to understanding tidal surges. It was developed by a Japanese mathematician who was experienced in tsunami modelling.

Electronic ocean model
1960–83

This device was built by the oceanographer Shizuo Ishiguro. It divided a body of water such as the North Sea into an electrical grid, with the flows of electricity designed to mirror those of the water. This modelling could help predict the strength, location and timing of storm surges.

Ishiguro began his career studying tsunamis on the Japanese coast. His move to Britain in 1956 was prompted by an increase in research funding after a devastating North Sea flood three years earlier. This research later supported the emerging North Sea oil and gas industry.

Find out more on the touch screen nearby.

Donated by: Shizuko Ishiguro
Object no: 2015-15

‘It had been known for quite a long time that surges are due to strong winds and changes in atmospheric pressure. But what we dearly want to know is when, where, how high the surge will be.’

Shizuo Ishiguro, 1968

Tide-predicting machine
1872

This machine was invented by the physicist and engineer William Thomson to predict the motion of tides. This was no simple matter in the 1870s.

First Thomson gathered a large amount of tide data from around Britain’s coastline. Then he used the mathematical technique known as harmonic analysis to break down the complicated tidal motion into a series of simpler components. Finally, he used this machine to recombine them for future tides. Cranking the handle for four hours gave him tidal predictions for one year.

Lent by: British Association for the Advancement of Science
Object no: 1876-1129

Model of a Thames Barrier pier
1982

A devastating flood hit the North Sea coast in January 1953. Water levels were so high they almost inundated London. In the disaster's aftermath, plans were made to build a huge barrier across the River Thames to protect the capital against future tidal surges.

The Thames Barrier, developed using elaborate mathematical modelling of the Thames Estuary, was finally completed in 1982. Its gates normally lie horizontally on the river bed out of the way of shipping, but when the models predict an emergency they can be rotated into a vertical position.

Object no: 1984-625

'There is a very real risk of an exceptional disaster in London from a North Sea surge and consequent flooding over a possible area of 60 square miles of the Greater London area. London has no insurance policy against this whatever.'

Roger Cooke, MP for Twickenham, 1968

Life and death

We have created remarkable medical tools and techniques to cure illness, ease pain and live longer.

In parallel we use mathematics to spot trends, understand statistics and help people reach their life's potential, as well as make provisions for the inevitable end.

Medical statistics

Medical statistics can be shocking. They represent the horrors of life and the agonies of death. But they only shock people into taking action if they are read and understood. And who wants to read endless rows of numbers?

During the Crimean War, Florence Nightingale saw tens of thousands of soldiers killed, most from preventable diseases rather than battlefield wounds. As a statistician she gathered data on the scale of carnage, and pioneered a graphical approach to show non-specialists the chilling Crimean statistics at a glance.

Mathematicians in the 20th century, such as Marie Reidemeister at the Isotype Institute, built on this concept. Today we are used to seeing statistics presented in graphical form. But in 1850s Britain this was revolutionary.

'England and Her Soldiers', by Harriet Martineau 1859

Harriet Martineau was a writer and journalist who wrote this book with Florence Nightingale, a statistician and nursing reformer. Nightingale ran British military hospitals in the 1850s Crimean War and was horrified by how many soldiers died from preventable diseases owing to the army's chaotic medical processes.

The book includes pioneering diagrams that Nightingale had developed to show, at a glance, the proportion of soldiers killed each month from disease. It was banned from the libraries in soldiers' barracks in case it damaged morale.

Find out more on the touch screen nearby.

Lent by: Florence Nightingale Museum, London
Object no: L2016-2002

‘Infant Death Rate and Income’
1933

In 1925, Otto Neurath and colleagues developed the ‘Vienna Method of Pictorial Statistics’. Later known as Isotype, this method for presenting and explaining health and other statistics had similarities with Florence Nightingale’s work.

This chart demonstrated the relationship between infant death rate and household income, showing that poor families suffered higher levels of child mortality. The Isotype approach can still be seen in many of today’s popular infographics in newspapers and on the web.

Lent by: University of Reading
Object no: L2015-4459

‘For a democratic society it is important to have a common knowledge in a common language.’

Otto Neurath, Isotype Institute, 1945

‘Women and a New Society’, by Charlotte Luetkins 1946

In the 1940s, as the Second World War came to an end, Britain was entering a new era of social reform with the foundation of the welfare state. This is one of a series of books examining critical changes in British society. It included statistical graphics from the Isotype Institute.

One diagram compared adult literacy between women and men over the period from 1841 to 1931. Marie Reidemeister, a mathematician who helped develop the Isotype method, had claimed ‘everyone knows that numbers are thoroughly unsuitable for spreading statistical knowledge’.

Lent by: University of Reading
Object nos: L2015-4460, L2015-4461

‘Estimated Cost and Personnel’
1950

After the Second World War the British Council assembled a series of study boxes for overseas students and workers to learn from British practice in areas such as health and welfare. The Isotype Institute prepared charts for the study box on the National Health Service. With pictures, ideas could be communicated across cultures.

Infographics like this – the word dates from the 1970s – are common in today’s media, but the ideas behind them go back to 19th-century statisticians, who understood the power of diagrams in presenting detailed statistics to the public.

Lent by: University of Reading
Object no: L2015-4462

Risk

To your right is a cabinet of tissue samples collected by the pathologist who first proved the link between asbestos and the lung cancer mesothelioma. Other stories in this section involve risks from toxic chemicals, vehicle exhaust emissions and radiation from X-rays.

This is not an easy story to think about. It involves our health – and the statistical likelihood that we will be harmed sometime in the future by exposure to something today. It is also about the routine decisions made day after day by medical professionals when our lives are in danger.

There are no simple answers. But by taking it upon ourselves to learn about probability and risk, we can make better decisions – and hold to account those whose decisions affect all our lives.

Tissue samples collected by Chris Wagner 1950–91

This cabinet holds tissue samples from the lungs of workers in South African asbestos mines who had died from mesothelioma, a rare lung cancer. They were collected by the pathologist Chris Wagner, who first proved a link between asbestos exposure and this deadly disease.

The problem is that some people can be heavily exposed to carcinogens without getting cancer. There are so many risk factors and such a long time between exposure and disease – years or decades – that there can be no certainty about who will be affected. But the statistical study of probability is a powerful tool to understand the likelihood of harm.

Donated by: Margaret Wagner
Object no: 2004-260

'None of these subjects can be remotely understood without an appreciation of probability, whether in weighing "risk factors" influencing the onset of coronary heart disease or in appreciating the statistical basis of environmental hazards.'

Bernard Dixon, former 'New Scientist' editor, on assessing the health risks that we face daily, 1982

Pedoscope shoe shop X-ray machine
About 1950

Visitors to shoe shops up to the 1970s might have used one of these machines. They were especially popular with children, who could see on the screen their feet inside their shoes. Parents and shop staff huddled over auxiliary screens to check how the shoes fitted.

A critical 1950 report raised concerns about the probability of damage caused by the X-rays, stating that ‘it is disturbing that any man, woman, or child can subject his or her own feet to unknown doses of radiation in a shoe shop’. But manufacturers dismissed these fears.

Donated by: Ferguson’s Footwear
Object no: 1985-774

Canister of DDT insecticide
1970

In 1962 a former US government biologist, Rachel Carson, wrote the book 'Silent Spring'. In it she expressed concern about harmful effects of pesticides such as DDT, used to control malaria-carrying mosquitoes and insect damage in crops.

The effect of 'Silent Spring' on the emerging environmental movement was powerful, as was the response of chemical companies, which criticised the book's findings. Risk deals in probability, not certainty, so statistics could be interpreted or distorted to suit particular viewpoints.

Donated by: Cussons (International) Ltd
Object no: Y1995.2.210

Catalytic converter removed for tests from a used car
1986

This is a catalytic converter from a Toyota Carina car with 50,000 miles on the clock. It was removed for tests at the UK's Transport Research Laboratory, which was studying vehicle emissions.

Toxic fumes from road vehicles had come increasingly under the spotlight in the 1970s, with growing concerns over long-term health risks. Catalytic converters reduced some harmful emissions, but there was no certainty about exposure and disease. The mathematical task was to quantify the likelihood, while the social and political challenge was to find the right balance between conflicting needs.

Donated by: Transport Research Laboratories Ltd
Object no: 1997-1822

London Hospital Survival Predictor
About 1972

Difficult decisions about probability and risk are made by hospital medical staff day in, day out. At the London Hospital in Whitechapel medics needed to decide the likelihood of patients in comas making recoveries.

This machine was built to help their diagnosis. It compared brain measurements from the coma patient with those from previous patients, stored in the machine's memory. The needle would then point somewhere between the letter 'S', meaning 'survive', and 'IBD', meaning 'irreversible brain death'. Nevertheless, the final decision about resuscitation was always made by doctors.

Donated by: St Bartholomew's Hospital
Object no: 1997-1918

Mortality

When are you going to die? Mathematics does not get much closer to life and death than when it is used to calculate how long we are likely to live. Life expectancy was what William Farr, the ‘superintendent of statistics’ for the British government, spent his career studying.

Farr pioneered the collection of official medical statistics and, in 1859, took delivery of the latest mathematical tool to help him do so – a difference engine. It is on display to your right.

Over the next five years, Farr used this new machine to help calculate figures for the ‘English Life Table’ of 1864, a huge book of numbers and equations that reduced human existence – joy, tragedy, hope, fear, love, loss, life and death – to cold statistics.

Scheutz difference engine
1859

‘English Life Table’
1864

Much of Victorian science, engineering and commerce made use of tables of numbers, calculated by hand by people known as ‘computers’. It was gruelling and tedious work.

This ‘difference engine’, invented by the mathematician Charles Babbage and brought to market by Georg and Edvard Scheutz, was an attempt to mechanise the process and reduce errors. It was bought by the British government to calculate figures for the ‘English Life Table’ of 1864. This mammoth publication included life expectancies of different parts of the population, and was used by insurance companies to price their premiums.

Donated by: Registrar-General
Object nos: 1914-122/1, 1914-122/4

‘The machine required incessant attention. Its work had to be watched with anxiety, and its arithmetical music had to be elicited by frequent tuning and skilful handling. This volume is the result, and thus the soul of the machine is exhibited in a series of tables.’

William Farr, government statistician, 1864

Babbage difference engine model
After 1871

Difference engines were machines that carried out simple arithmetical calculations over and over again. Without them, the work had to be done by hand – and it was tedious, laborious and prone to errors. Yet the results could be vital, underpinning science, engineering and commerce.

The difference engine was invented in the 1820s by the mathematician Charles Babbage. He built working models but never completed his machine. This demonstration model was assembled after his death by his son, using parts left over from his father's abortive project.

Donated by: University College London
Object no: 1967-70

'I wish to God these calculations had been executed by steam.'

Charles Babbage, checking a table of hand calculations, 1821

‘An Estimate of the Degrees of the Mortality of Mankind’, by Edmond Halley
1693

This academic paper, published in 1693 by the astronomer Edmond Halley, was the first attempt to put the mathematics of mortality onto a rigorous footing. It showed how to calculate the price of insurance premiums and other financial products.

Halley’s work was relatively simple, as he was hampered by a lack of computing technology. The insurance industry today has developed highly sophisticated theories and technologies to put a price on a breathtaking array of products.

Source: Science Museum Library

Pension slide rule
1850s

This complicated slide rule was invented by John Hannyngton, a prominent life insurance and pensions administrator (or actuary) working for the British government in India from the 1850s. It was used in government offices into the 1940s.

Hannyngton controlled millions of pounds of pension and insurance funds which directly affected the lives of countless soldiers and their families. He was an early user of new calculating machinery, believing it would relieve actuaries of tedious work.

Donated by: A C Rohde
Object no: 1971-415

'I am persuaded that the days of hand work in the actuary's craft are coming to an end.'

John Hannyngton, 1865

Insurance office calculating machine
About 1885

The insurance industry relies on mathematics throughout its business, whether in the calculation of premiums or the administration of customers' accounts.

The Prudential Assurance company was the first to offer insurance products to the masses. To cope with its huge volume of data processing and calculation, the Prudential was an early adopter of new technologies that made this work more efficient. This 'arithmometer', a mechanical desktop calculating machine, was custom-designed for the company in the 1880s.

Lent by: Wellcome Trust
Object no: 1989-636

Image: The machine repair room at Prudential Assurance headquarters, London. An arithmometer can be seen being repaired centre left.

Courtesy of Prudential plc

Measuring people

We go through life having our bodies measured and classified. Today it is a vital medical practice to compare us with other citizens and improve our life chances, but 200 years ago it caused a sensation.

On a lecture tour in 1805, the physician Franz Joseph Gall would present hundreds of human skulls. Demonstrating each in turn, he claimed he could use its shape to read the personality of the dead person. Scientists attacked his ideas for their lack of evidence.

Decades later, the statistician Francis Galton began his own project to measure the physical features of thousands of people, from eye and hair colour to height, strength and head size. Unlike Gall, Galton was no showman. He wanted to gather enough data to reshape the human race.

Human skulls with phrenological markings
19th century

Human skull, 19th century
Lent by: Wellcome Trust
Object no: A650862

Human skulls, 19th century
Donated by: Wellcome Institute
for the History of Medicine
Object nos: 1999-396,
1999-398, 1999-399, 1999-405

The Austrian physician Franz Joseph Gall believed that the contours of people's heads reflected their personality, and that skulls could be 'read' to see whether the person was compassionate, arrogant, witty or murderous. This practice became known as phrenology.

Phrenology was popular with the public, but soon discredited by scientists as the proposed link between skull shape and personality could not be proved by statistical data. However, it did pave the way for a new science – anthropometry, the measuring and classifying of people. Scientists working on later anthropometric projects developed the rigorous statistical techniques still used in mathematics today.

Glass eyes used in statistical experiments 1884

These artificial eyes in a range of colours were used to measure visitors at a South Kensington exhibition. Founded by the statistician Francis Galton in 1884, this ‘anthropometric laboratory’ (anthropometry means the measurement and classification of humans) received 10,000 visitors in its first year.

Each visitor was subjected to 17 different measurements which, alongside their eye colour, included their height, weight, strength, hearing, sight and lung capacity. Galton believed the statistical data he gathered could be used to understand better the population as a whole.

Lent by: University College London
Object no: L2016-2004

Image: Francis Galton’s anthropometric laboratory at a South Kensington exhibition.

Science Museum/Science & Society Picture Library

Intelligence tests for pre-school children 1948

The 'Merrill-Palmer Scale of Mental Tests' shown here was first devised in 1931 and was used to test the mental abilities of children aged from 18 months to six years. This particular set was used in the psychology department at Alder Hey children's hospital, Liverpool.

Psychologists have been measuring children's intelligence for over a century. The results are often used to rank children on a statistical spectrum of intelligence compared with others. However, many people argue that these tests are biased against certain groups in society.

Donated by: Centre for the History of Psychology
Object no: 2000-903

Image: Merrill-Palmer tests being used by a researcher in 1932.

Courtesy of Wayne State University Archives

Height and weight chart
1992

Throughout people's lifetimes their height and weight are regularly measured as a check on healthy development. The idea of plotting height and weight onto a chart dates back to the 18th century and is crucial to child health today. It measures people against a statistical average and classifies them as normal or abnormal.

This chart was used in developing countries to monitor children's growth. It allowed nurses to see at a glance whether children were heavier or lighter than average for their height.

Object no: 1992-891/1

Money

Money makes the world go round. Some of the earliest mathematical innovations came from our desire to keep what we have – and get more of it.

From counting and gambling to understanding the world's economy, where there is money there is mathematics.

Gambling

We have been playing the National Lottery in the UK since 1994, when Prime Minister John Major set up the money-raising scheme and the BBC broadcast the first weekly draws using machines such as ‘Guinevere’, displayed to your left. Millions around the country were glued to their television sets, hoping their numbers would come up.

People have been playing games of chance since before recorded history. Archaeologists have found evidence that early people used certain animal bones as rudimentary dice. But it was not until the 17th century that the mathematics of chance was understood.

It is no coincidence that the world’s most talented mathematicians often used the throw of the dice to help work out the complexities of probability theory. Gambling helped them think through their mathematical ideas.

National Lottery machine 'Guinevere' 1994

Meet 'Guinevere', one of three random-number-selecting machines used in the UK's National Lottery live draws held since November 1994. Each week, as host Noel Edmonds whipped the crowds at BBC Television Centre into a frenzy of anticipation, all eyes focused on its dropping balls.

One at a time, the numbers flashed up on millions of television screens across the country. Somebody was about to become a millionaire. Yet for all its modern glitz, the machine was performing an ancient and venerated statistical task – the selection of a random number. We have had technology to do that for thousands of years.

Donated by: Camelot Group plc
Object no: 2006-207

'Guinevere' is a registered trade mark of the National Lottery Commission and is used with its consent.

'It is arguable whether we should have huge prizes and pay-outs or more large ones. After all, £1 million, £2 million or £3 million is a huge amount to any of us. The mathematics of happiness are ambiguous.'

Mark Fisher MP, National Lottery parliamentary debate, 1994

Bookmaker's settling machine
1972

This electronic calculator was used by betting-shop assistants to work out winnings in complicated multi-race bets. It simplified the arithmetic into a step-by-step process described above the keys. The final operation in every transaction was to press the 'tax' button.

The gambling industry makes billions of pounds each year in the UK alone, not including the National Lottery. In 2016 the government took £1.7 billion in gambling taxes. Gambling is a huge business and employs some of the most talented mathematicians, many poached from university mathematics departments.

Donated by: Janis Stein
Object no: 2009-61

Pair of dice
About 1900

Dice were first made about 5000 years ago. Humans had been playing games of chance since before recorded history, and dice allowed them to pick random numbers with equal probabilities.

In the 17th and 18th centuries leading mathematicians used dice as inspiration to work out mathematical theories of probability. Today these underpin everything from finance to genetics, and from climate science to the study of epidemics.

Object nos: 1980-676/87, 1980-676/88

Dog-racing tote machine
About 1933

This is part of a huge electromechanical machine from Wembley Greyhound Stadium. The machine, known as a totalisator or tote, calculated the odds for each dog in real time as gamblers placed their bets. It also operated a giant display screen.

Tote betting was different from betting with track-side bookmakers, who all set their own odds. With the tote, everyone paid into a single pool. Winnings resulted from a mathematical calculation on the bets placed on each dog. Punters no longer needed to shop around for the best odds.

Find out more on the touch screen nearby.

Donated by: Wembley Stadium Ltd
Object no: 2000-829

‘The sport of dog racing is a new-comer to these islands, an immigrant, like many other things good and bad, from the other side of the Atlantic.’

John Buchan, MP and novelist, 1928

How the economy works

Bill Phillips endured his time in a Japanese prisoner-of-war camp by building machines. He was an engineer, so making things helped him make sense of the world.

After his release he became an economist, having been taught that the economy operated according to a set of mathematical equations. But there was a problem. How could the economy be understood by non-mathematicians? Phillips's answer was to make machines that could solve the equations in live demonstrations. One of them is shown on your left. Other economists made devices that simplified the calculations.

But sometimes the rules get broken and things get out of hand. Crucial to understanding the economy is understanding the limits of the mathematical models.

London School of Economics ‘Moniac’
1952

This machine modelled the British economy using the flow of water to represent money. It was made for the London School of Economics in 1952 by Bill Phillips, an engineer turned economist.

Economists such as Phillips used mathematical equations to describe economic behaviour, and this machine solved them in a visual way. The lower tank represented the nation’s stock of money, which emerged as spending, saving, taxes and international trade. It was sophisticated, but many economists now believe the economy is more complicated than the simple equations that this machine was based on.

Find out more on the touch screen nearby.

Donated by: Suntory-Toyota International Centre, London School of Economics
Object no: 1995-210

‘With interest in popular economic education and the need for demonstrating fiscal problems before congressional committees, the Moniac may have appeal for teaching “economics in thirty fascinating minutes”.’

‘Fortune’ magazine, 1952

Economics equation-solving machine
1885

This is a device for solving equations using curves. The metal protractor was placed over the printed graph and used to read results from it directly. It was created by Henry Cunynghame, an economist who influenced John Maynard Keynes.

Economists and retailers use equations and curves to understand economic behaviour. Take consumer demand, for instance. Plot the price of goods against the quantity that consumers are willing to buy at that price, and the result is a graph which helps set the best price. There are many other examples of curves and equations in economics.

Donated by: Henry Cunynghame
Object no: 1885-43

‘Some of the most important contributions to statistical theory have been made by mathematical economists.’

Henry Ludwell Moore, economist, reviewing Cunynghame’s work, 1905

‘Moneywise’ magazine
December 1990

We should all arm ourselves with knowledge about how the economy works. ‘Moneywise’ magazine, launched in July 1990, was one product designed to help us. This December 1990 issue contained a ready reckoner for calculating mortgage repayments, as well as articles on tax, savings, pensions and banking.

Knowledge of the mathematics of money gives us power. The government routinely makes economic decisions which directly affect our lives, our families and our future. How can we hold politicians to account without understanding at least the basic underlying principles of money and the economy?

Donated by: Jon Darius
Object no: 1993-194

Lotus 1-2-3 spreadsheet software
About 1983

Financial traders need to decide the prices at which they will buy and sell products such as shares, bonds and mortgages. Lotus 1-2-3, along with other popular spreadsheets such as VisiCorp VisiCalc and Microsoft Excel, profoundly changed the way these traders worked.

Before desktop computers and spreadsheets became common, traders had to send pricing models for computer processing overnight. Using spreadsheets they could work out prices in a few minutes.

Find out more on the touch screen nearby.

Donated by: Paul Blitz
Object no: 2013-57/4

Counting

People who work in shops and bars handle numbers constantly. Bank tellers and accounts clerks deal with a relentless flow of payments. Sports fans analyse match statistics and householders juggle weekly budgets. In fact, most of us carry out arithmetic every day at work, home and play.

Arithmetic – counting – may be mundane but it is an ancient and vital part of our everyday lives. We count all the time. We should celebrate our ability to handle numbers. It is like writing or talking.

Sometimes we turn towards technology to help out. We have been making devices to help us count for thousands of years, from abacuses to pocket calculators. More often than not we use them to help keep track of money.

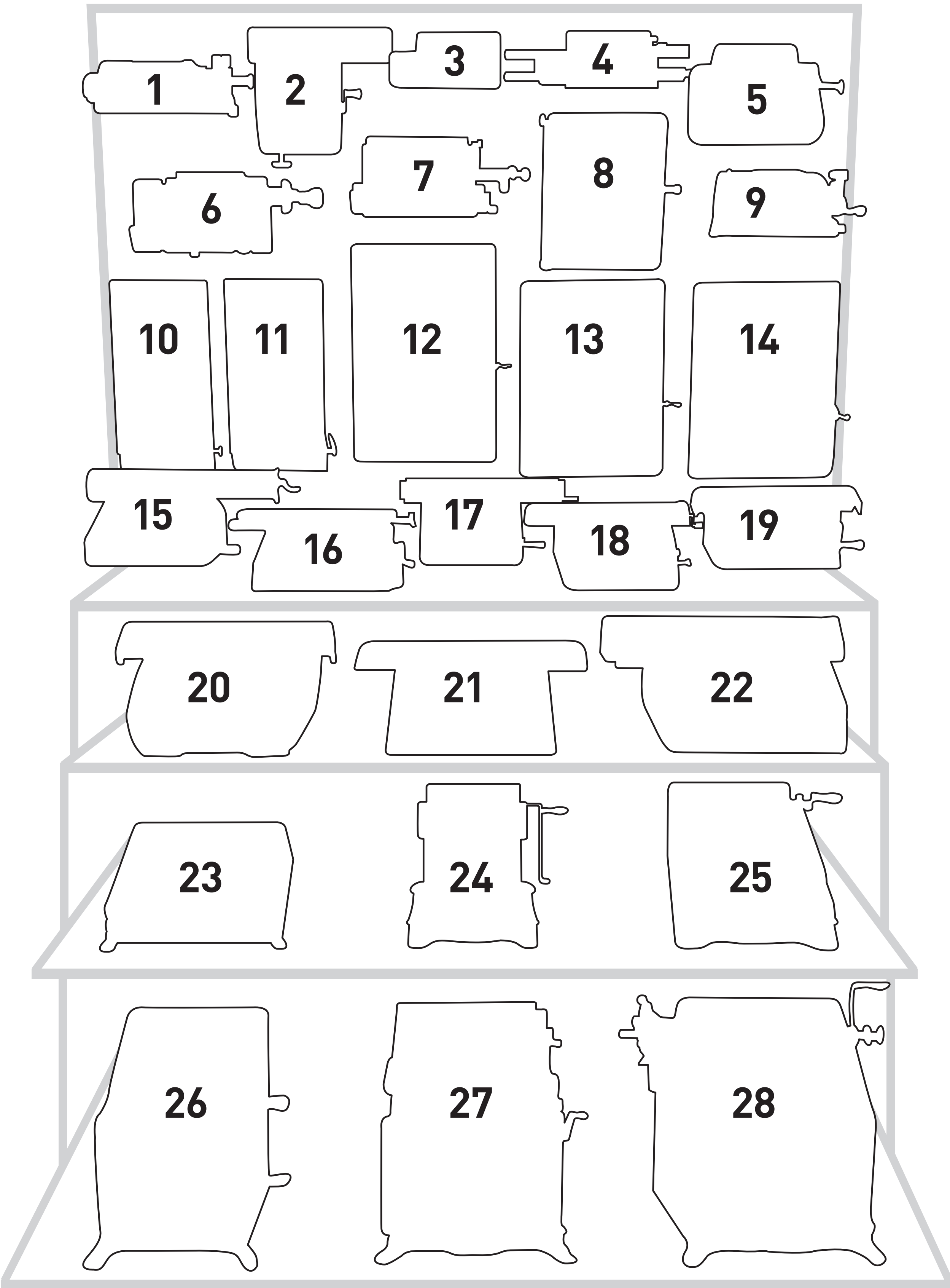
Mechanical calculating machines 1900–70

Commerce and industry expanded rapidly in the 18th and 19th centuries. Huge amounts of money flowed around the world's economy and it all needed to be totted up, banked and recorded.

To help meet this demand for mass calculation, powerful desktop calculating machines were installed in banks, factories, offices and shops to keep track of money. Vast numbers of calculators like the ones on show were in use by the early 20th century, but they were difficult to operate and required extensive training. Operators often sat in long rows amid deafening noise as they worked at identical machines.

Image: Clerks at the US Treasury Department calculating bonuses, 1924.

Courtesy of National Photo Company Collection, Library of Congress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1. Brunsviga calculating machine, about 1970
Donated by: Merton Technical College
Object no: 1981-674

2. Monroe calculating machine, about 1960
Donated by: W S Narracott
Object no: 1980-95

3. Multo calculating machine, about 1960
Donated by: Imperial College of Science and Technology (Lyon Playfair Library)
Object no: 1987-364

4. Multo calculating machine, about 1960
Lent by: DERA Haslar, Froude Museum
Object no: 1997-2302

5. Hamann Manus R calculating machine, about 1954
Object no: 1990-455

6. Triumphator calculating machine, about 1955
Donated by: Ipeco Europe
Object no: 1995-200

7. Muldivo calculating machine, about 1960
Donated by: Imperial College of Science and Technology (Lyon Playfair Library)
Object no: 1987-361

8. Burroughs calculating machine, about 1920
Donated by: Imperial College of Science and Technology (Lyon Playfair Library)
Object no: 1987-368

9. Muldivo Mentor calculating machine, about 1955
Donated by: R McWilliam
Object no: 1991-391

10. Comptometer calculating machine, about 1900
Donated by: Felt and Tarrant Manufacturing Company
Object no: 1911-255

11. Comptometer calculating machine, about 1900
Donated by: Taylor's Typewriter Company
Object no: 1952-67

12. Comptometer calculating machine, about 1915
Donated by: E Marsh
Object no: 1991-369

13. Comptometer calculating machine, about 1920
Donated by: T Beaumont
Object no: 1986-1064

14. Comptometer calculating machine, about 1935
Donated by: Prudential Assurance Company
Object no: 1974-507

15. Lagomarsino-Numeria calculating machine, about 1965. Donated by: Thames Polytechnic
Object no: 1988-177

16. Madas calculating machine, about 1965
Object no: 1980-125

17. Flying Fish calculating machine, about 1965
Donated by: Qantas Airways Ltd
Object no: 1992-1000

18. Monroe calculating machine, about 1965
Donated by: Thames Polytechnic
Object no: 1988-178

19. Madas calculating machine, about 1960
Donated by: Transport Research Laboratories Ltd
Object no: 1998-30

20. SCM Marchant calculating machine, about 1960
Donated by: Imperial College of Science and Technology (Lyon Playfair Library)
Object no: 1987-362

21. Diehl calculating machine, about 1960
Donated by: Imperial College of Science and Technology (Lyon Playfair Library)
Object no: 1987-359

22. Monromatic calculating machine, about 1960
Donated by: City University (School of Mathematics)
Object no: 1976-361

23. Burroughs calculating machine, about 1945
Donated by: Bank of England
Object no: 1981-2067

24. Burroughs calculating machine, about 1935
Donated by: T Beaumont
Object no: 1986-1063

25. Burroughs calculating machine, about 1930
Donated by: Midland Bank Ltd
Object no: 1976-328

26. Burroughs calculating machine, about 1913
Donated by: Unisys Ltd
Object no: 1913-534

27. Burroughs calculating machine, about 1917
Donated by: Bank of England
Object no: 1966-333

28. Burroughs calculating machine, about 1930
Donated by: Midland Bank Ltd
Object no: 1976-327

‘With his Burroughs, Mr Nickles knows, each day, his sales, costs and profits. He knows which goods bring most profit and which clerks sell profit goods. This knowledge helps him to make more money.’

Burroughs calculating machine brochure, describing a Wisconsin store-owner, about 1890

Shop cash register
About 1970

The sound of the cash register has become an icon for consumer spending and the acquisition of money. Love shopping or hate it, we live in a consumer economy, and the cash register records every transaction.

Mass manufacture in the 19th and 20th centuries brought us a breathtaking array of new consumer goods. Over time more and more people became affluent enough to afford them. From the Victorians onwards, checkout operators in every shop have totted up goods, day in and day out, on registers like this.

Object no: 1991-373

Electronic pocket calculator
1973

The first pocket calculators were invented over 350 years ago, but they were made with gearwheels and mechanical dials. Adding and subtracting numbers was the best they could manage.

Fast-forward to the 1970s and we started buying electronic calculators. Early ones like the machine on display were expensive, but by the 1980s they had become cheap and ever more powerful. Educators feared children would lose the ability to carry out mental arithmetic.

Donated by: Sinclair Radionics Ltd
Object no: 1974-505

Abacus
About 1900

Abacuses have been used for thousands of years and are still widely used today to teach arithmetic. They can also be used by skilled operators to carry out arithmetic more quickly than by using a pocket calculator.

This early-20th-century Russian abacus was used by clerks to count money. The top row represents quarter-kopecks. The next holds kopecks, then tens of kopecks, then quarter-roubles. The remaining rows represent roubles, from units to millions. In 1927 its owner explained that many operators 'attained an extraordinary virtuosity' as it was 'simple, untiring and productive'.

Donated by: Professor S F Ivanov
Object no: 1927-912

Set of Napier's rods
About 1690

Seventeenth-century merchants faced with laborious multiplication and division rejoiced when John Napier published details of his new gadget in 1617. His devices were known as 'Napier's rods', simple sets of numbered strips.

Napier's rods were based on an Islamic arithmetical technique known today as lattice multiplication, which is still used for multiplying and dividing numbers. Napier explained that 'to perform calculations is a difficult and lengthy process, the tedium of which deters many from the study of mathematics'.

Donated by: Major-General H P Babbage
Object no: 1905-111

Calculating machine
About 1670

This is one of the earliest mechanical calculating machines in Britain. It was invented in 1666 by the mathematician Samuel Morland for counting money quickly and accurately.

The machine has individual dials for farthings, pence and shillings, as well as for pounds, from units to tens of thousands. A stylus rotated the dials – clockwise for addition, anticlockwise for subtraction. Counters kept track of totals. Several were made, one being shown to the diarist Samuel Pepys. He described it as ‘very pretty, but not very useful’.

Donated by: Major-General H P Babbage
Object no: 1905-109