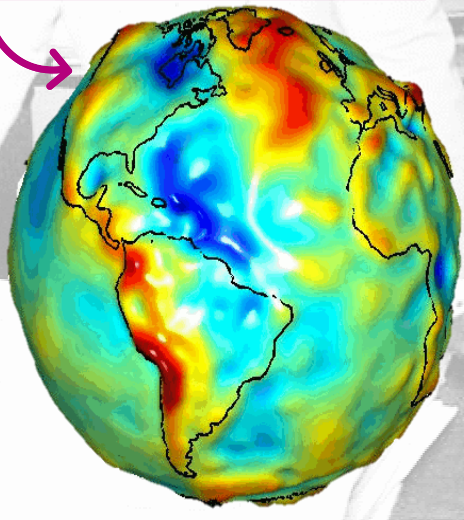
Dr Gladys West (1930 – Present)

Computer programmer credited with the invention of the GPS

"I had to be the best that I could be, [. . .] always doing things just right, to set an example for other people who were coming behind me."

The work of Gladys West enabled the creation of the GPS. This was done through her analysis of satellite altimeter data from the NASA Geodetic Earth Orbiting Programme. This was the foundation of her work to programme an accurate geopotential model of the earth, a Geoid. This model then served as the basis of the GPS. Her complex algorithms were able to account for all factors impacting the shape of the Earth and its irregularities.



Born in 1930's Virginia, West felt certain she would follow in the footsteps of her parents, a work in the farms and tobacco plants, however her determination and aptitude for maths allowed for her to pursue a career in computer programming and modelling.

Graduating from Virginia State University in 1955, following a stint as a teacher in segregated schools, West was hired by the U.S Navy, where she was one of four black employees. Her work here involved: determining the movements of Pluto in relation to Neptune, project manager of SESAT (a satellite used to provide data on oceanographic conditions, and then eventually the development of the mapping of the Geoid.

West did not receive recognition for her work until the early 2000's and receiving her first award for her work in 2018. In more recent times being known as a *'Hidden Figure'* in history. However, she did not aim for recognition only for academic excellence. Notably earning her PhD in public administration and policy affairs at the age of 70, two years after her retirement.

"I have realised my dreams and reached a height beyond what I anticipated. I encourage young women to believe in yourself, find your passion, work hard […] and most of all – follow your dreams"

Scan for a short video

Awards:

2018 – Inducted into the United States Air Force Hall of Fame

2018 – Female Alumna of the Year at the Historically Black Colleges and Universities Awards

2018 – Featured in the BBC's list of '100 Women'

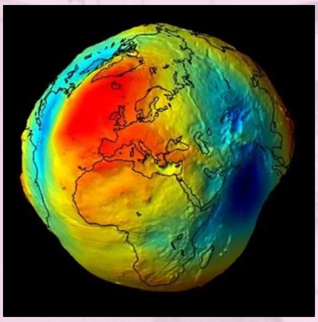
2021 – The first female to be awarded the Prince Philip Medal by the Royal Academy of Engineering (the highest individual honour)

Dr Gladys West (1930 – Present)

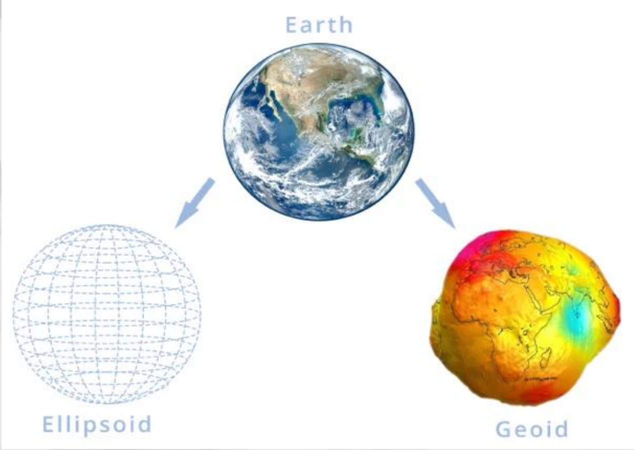
Queen Mary University of London

Computer programmer credited with the invention of the GPS

Geoid: a more realistic model figure of Earth than the ellipsoid



GPS must correct for real variations in Earth's shape, which is where the geoid comes in. The earth is bumpy and irregular, affected by mountains, valleys, and gravity variations. The geoid represents mean sea level, extended under the continents.



The ellipsoid is the mathematical 'ideal earth'. GPS satellites calculate your position based on distances from space. Those distances require a clean, mathematical surface to reference, and that is the ellipsoid.

$$N = \sum_{n=2}^{\infty} \sum_{m=0}^{n} (C_{nm} \cos m\lambda + S_{nm} \sin m\lambda) P_{nm}(\sin\phi)$$

Spherical harmonic expansion used in GPS geoid modelling to describe the Earth's gravity field. This is the kind of mathematics Dr West worked with at the Naval Surface Warfare Centre.

N: geoid height (how much the Earth's true gravity surface deviates from a perfect reference ellipsoid)
n: degree (controls the size of features, is low when features are large-scale e.g. continents and high when features are small-scale e.g. mountain ranges)
m: order (ranges from 0 to n for each degree, controlling variation around longitude)
C_{nm} **and** S_{nm}: cos and sin coefficients (measured constants derived from satellite data)
λ **and** ϕ: angular longitude and geodetic latitude variables
$P_{nm}(\sin\phi)$: associated Legendre functions (describe how the gravity field varies from equator to poles, ensuring the solution works correctly on a sphere)

```
FOR each satellite observation:
    COMPUTE distance to ellipsoid
    UPDATE geoid model
```

Dr West coded algorithms to calculate the true shape of the Earth from satellite data.

QUESTION: A GPS model uses only one term of the spherical harmonic expansion: $N = C_{20}P_{20}(\sin\phi)$
Given $C_{20} = -4.8 \times 10^{-4}$ and $P_{20}(\sin\phi) = 0.25$, calculate the geoid height contribution N from this term

Answer: $N = -1.2 \times 10^{-4}$

Mary Somerville (1780 - 1872)

Queen Mary University of London

Brought continental calculus to Britain, known as the 'Queen of Science'

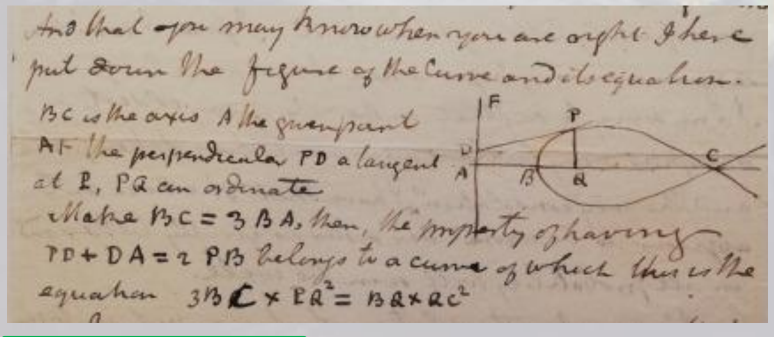
"Whatever difficulty we might experience […] in choosing a King of Science, there could be no question whatever as to the Queen of Science." – The Morning Post 1872

A Scottish writer and Polymath who is dubbed as the worlds 'first ever scientist' as well as one of the first female members of the Royal Astronomical Society. Awarded a silver medal in 1811 for solving the Diophantine problem, which included 'Fermat's Last Theorem', thought to have been unsolvable for 400 years. In addition to this, she can be credited with being one of the first people to suggest Neptune's existence and mentoring Ada Lovelace.

Somerville grew up as one of six children, and unlike her brothers, did not receive formal schooling as a young child, only being taught to read by her mother, but not to write. Her first interaction with science came from her art teacher who introduced her to 'Euclid's Elements'. In 1817 she was introduced to the works of Laplace, Poisson and Poinsot whilst visiting Paris. Following this visit, Somerville used her connections in Paris to bring these concepts to Britain.

<u>Scientist (noun):</u>
First used in print in 1834 in William Whewell's anonymous review of Somerville's work, ' The Connexion of the Physical Sciences'

Somerville was the first person to be dubbed a 'scientist' in print, as her work was becoming so separate to the standard terminology at the time of 'philosopher'. She was a revolutionary in her field.



"Age has not abated my zeal for the emancipation of my sex from the unreasonable prejudice too prevalent in Great Britain against a literary and scientific education for women".

Somerville had to work hard to gain acceptance for her work, and at the start of her career, even publishing under the pseudonym, *'A Lady'* to avoid scrutiny. She even described her husband as having 'a very low opinion of the capacity of [her] sex'

Always keen liberal ,she was the first supporter of Mill's petition to Parliament to grant female suffrage as well as advocating for abolition of slavery.

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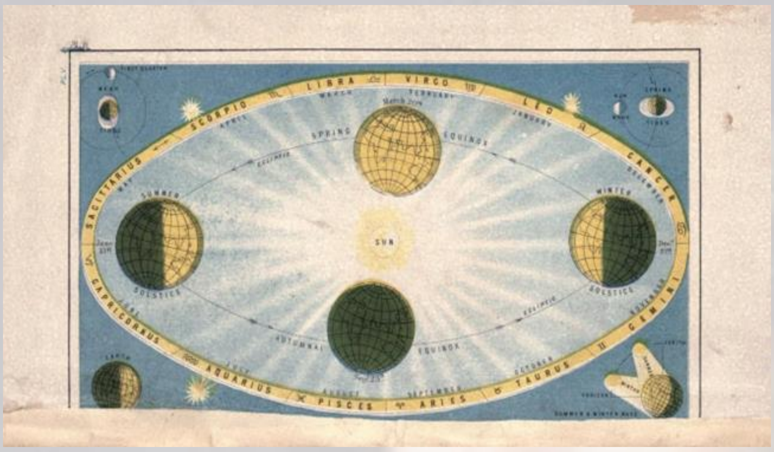
Mary Somerville (1780 - 1872)

Queen Mary University of London

Brought continental calculus to Britain, known as the 'Queen of Science'

In 1831, age 50, Mary published 'The Mechanism of the Heavens'. This was her translation of the first two volumes of Pierre Laplace's 'Méchanique Céleste'.



Somerville's explanations of celestial mechanics helped bring Laplace's work to the English-speaking world.

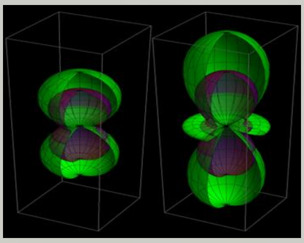
This illustration from '*The Mechanism of the Heavens*' depicts the Earth's orbit around the sun and is used to explain the changing of the seasons and the zodiac.

$$P_2\,(\cos\theta) = \frac{1}{2}(3\cos^2\theta - 1)$$

P_2: Legendre polynomial of the second order
θ: the polar angle (measured downward from the positive z-axis)

This equation shows the second Legendre polynomial which Mary Somerville used in explaining celestial mechanics and gravitational theory. It is fundamental in physics and astronomy, as it is used to describe spherical harmonics, which are essential for applications such as calculating gravitational potential, predicting planetary orbits and calculating tidal forces.

This diagram shows a 3D visualisation of this polynomial, representing how a physical quantity varies across the surface of a sphere.



$$\mathbf{F} = \frac{Gm_1m_2}{r^2}$$

Newton's formula for gravitational attraction between two objects.

Somerville essentially 'translated' Newton's geometric physics into the language of Continental Calculus, using his formulations as mathematical explanations for complex systems and phenomena that he himself couldn't fully solve, such as the stability of the solar system (Newton was famously worried that the mutual gravity between planets would eventually make the solar system unstable).

She accounted for the fact that the planets are spheroids, using the formula to calculate how every individual particle of a planet attracts every other particle, allowing her to explain why the Earth's shape and rotation cause gravity to be slightly different at the poles than at the equator.

QUESTION: Using the above formula for the second Legendre polynomial, calculate the value of P_2 at the Earth's equator (HINT: at the equator, $\theta = 90°$)

Answer: $P_2(\cos(90°)) = -0.5$

The negative value here corresponds to the 'pull' or displacement away from a perfect sphere, mathematically describing the Earth's oblate shape!

SCHOOL OF ENGINEERING AND MATERIALS SCIENCE – 'DIVERSIFYING STEM CURRICULA'

Katherine Johnson (1918 – 2020)

The 'Hidden Figure' behind the calculations for NASA moon landings

Queen Mary University of London

"I wasn't going to let the fear of not being able to do something dominate the rest of my thoughts and my plans."

Katherine Johnson was a trailblazing mathematician whose groundbreaking work at NASA was crucial to the success of the U.S. space program. Despite facing racial and gender discrimination, she made significant contributions to projects such as John Glenn's orbital flight, the Apollo missions, and the Lunar Orbiter Program, performing complex calculations that ensured the safety and success of these missions. Johnson's expertise was so respected that Glenn specifically requested her to verify computer-generated calculations for his mission. Her career broke barriers for women and African Americans in STEM, inspiring generations and cementing her legacy as one of the most influential figures in space exploration history.

Showing an exceptional mathematical talent from a young age, Johnson attended high school by the age of 10. Going on to graduate summa cum laude from West Virginia State College at 18, earning degrees in mathematics and French. She became one of the first African American women to attend graduate school at West Virginia University in 1939, where she was chosen as one of three Black students to integrate the graduate program. Her strong foundation in mathematics and her determination set the stage for her groundbreaking career at NASA.

Katherine Johnson began her career at the National Advisory Committee for Aeronautics (NACA), the precursor to NASA, in 1953, after hearing about job openings for African American women with strong mathematics skills. She was hired as a "human computer". Her exceptional talent quickly stood out, and within weeks, she was reassigned to the Flight Research Division, where she worked on critical aerospace projects. At NASA, she calculated flight trajectories, launch windows, and emergency return paths for missions such as Alan Shepard's first American manned flight and John Glenn's historic orbital mission. Johnson's expertise in celestial navigation was instrumental to the success of later missions, including the Apollo moon landings, where she helped ensure safe paths for astronauts to and from the Moon.

"Some say, 'I don't bother anybody, and nobody bothers me.' But that's not a quote from a leader. We have to accept challenges, be open and honest."

The 2016 film *'Hidden Figures'* brought Johnson's story to a global audience, highlighting her and her colleagues' often overlooked contributions to NASA during the space race. In recognition of her groundbreaking work and impact on space exploration, Johnson was awarded the Presidential Medal of Freedom in 2015

Scan for a short video

Katherine Johnson (1918 – 2020)

The 'Hidden Figure' behind the calculations for NASA moon landings

Johnson worked with very complex mathematics, computing early spaceflight trajectories, orbits and re-entry paths which made space travel possible.

Johnson hand-calculated orbital transfer paths in the early days of NASA flight dynamics. Orbiting Earth isn't as simple as just 'going around in a circle', and accurate mathematics is needed to move into, stay in and leave an orbit. Therefore, Johnson's mathematics was needed to calculate a stable orbit around earth: for example, John Glenn's spacecraft, for which Katherine calculated the orbit and re-entry path, made three planetary orbits before re-entering the atmosphere. If the calculations had been wrong, the capsule would have missed its orbit, burnt up on re-entry, or landed far off course with no option for rescue.

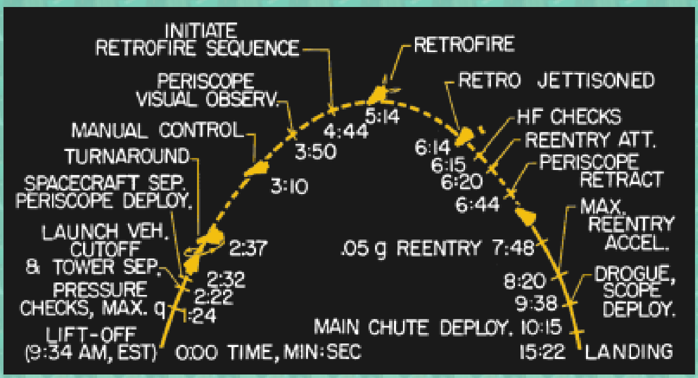
$$s = ut + \frac{1}{2}at^2$$

$$v = \sqrt{\frac{GM}{r}}$$

Johnson had to calculate paths in space by hand, accurately and quickly with no room for mistakes.

Katherine used equations such as the SUVAT equations to compute orbital motion before electronic computers were trusted. John Glenn famously asked NASA to "get the girl to check the numbers" before his launch, showing that he trusted her mathematics more than the computer.

"A Real Fireball Outside"
John Glenn- Mercury Spacecraft Friendship 7 Re-entry with retropackage in place- Feb 20, 1962



Katherine Johnson's trajectory analysis for Alan Shepherd's May 1961 Freedom 7 Mission, which was the first U.S human spaceflight.

"The early trajectory was a parabola, and it was easy to predict where it would be at any point. Early on, when they said they wanted the capsule to come down at a certain place, they were trying to compute when it should start. I said, 'Let me do it. You tell me when you want it and where you want it to land, and I'll do it backwards and tell you when to take off." ***–Katherine Johnson***

QUESTION:

During launch, John Glenn's spacecraft starts from rest and accelerates upwards at $a = 9.8\,ms^{-2}$. Given $G = 6.67 \times 10^{-11}\,Nm^2kg^{-2}$, mass of Earth $= 6.0 \times 10^{24}\,kg$, distance from Earth's centre $= 6.8 \times 10^6\,m$:

a) Calculate the distance the spacecraft travels in the first 12 seconds of launch

b) Calculate the orbital speed of John Glenn's spacecraft

Answers: a) $s = 705.6\,m$ b) $v \approx 7670\,ms^{-1}$

Nira Chamberlain (1969 – Present)

Queen Mary University of London

OBE recipient for services to mathematics

"My name is Prof. Nira Chamberlain, and I am proud to be a mathematician."

"Mathematics is indisputably the greatest subject in the world! Why? Because it is the language of the world. Mathematics crosses racial, geographical and cultural boundaries."

Chamberlains career spans over several industries, from aerospace, energy, defence and finance. His use of modelling has provided solutions to real world issues, one of the most notable being his cost capability trade-off for HMS Queen Elizabeth, modelling the lifetime running costs of aircraft carriers versus operating budgets. This was later included in the Encyclopaedia of Mathematics, making him one of the few British mathematicians included.

Chamberlain studied mathematics at Coventry Polytechnic, graduating in 1991, followed by a Masters in Industrial Mathematical Modelling from Loughborough University. He then rounded off his initial academic career with a PhD from Portsmouth University writing a thesis titled *'Extension of the Gamblers Ruin Problem Played Over Networks'*.

A regular speaker for the charity 'Speaker for Schools', which focuses on inspiring state-school students to maximise their potential, Chamberlain is a champion for diversity within the mathematical sciences.

His lecture entitled: *'The Black Heroes of Mathematics'* is a part of his mission to highlight the lack of black role models in mathematics and as proof that anyone can make it in the field. As a child, Chamberlain was discouraged from pursuing mathematics and was a victim of bullying via his peers. He used this to spur him on, and when his son experienced the same treatment, Chamberlain pushed harder to fight the stereotypes being forced onto him.

Scan for a short video

Achievements:

2018 - Powerlist's 5th Most Influential Black Person in the U.K

2018 – named the 'World's Most Interesting Mathematician'

2019 – Top 100 'Most Influential BAME Leaders' in U.K Tech Sector

2020 – Honorary member of the Mathematical Association

2022 – OBE for services to Mathematics

2023 – First Black President of The Mathematical Association

Nira Chamberlain (1969 – Present)

Queen Mary University of London

OBE recipient for services to mathematics

The 'Gambler's Ruin Problem' and Stopping an AI Apocalypse

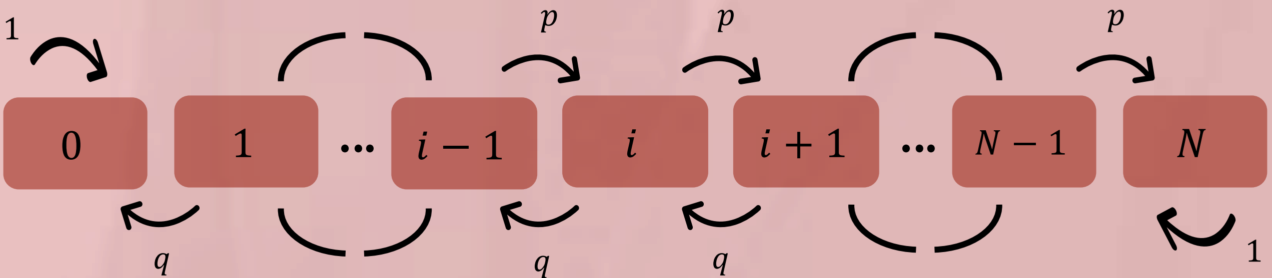
October 2024: Chamberlain hosted a talk at Nottingham Trent University discussing a hypothetical future where AI takes over the world economy. Using his PhD work on 'the gambler's ruin problem played over networks', he modelled a business wargame between AI and non-AI businesses to investigate.

The Gambler's Ruin Problem: A 1-Dimensional Example

A gambler starts with £i where $0 < i < N$. They play a series of games; each time, they bet £1 until they have either £N or £0. Given the game is fair, what is the probability P_i the gambler wins £N ? What is the expected duration E_i of the games?

Click here to watch the talk!

Let p be the probability of winning a single game and q be the probability of losing such that $p = q = 0.5$.



The above is a Markov chain for the scenario. $i = 0$ and $i = N$ are absorbing states, so the probability of the gambler leaving is 1.

Using a recurrence relation, $P_i = 0.5P_{i+1} + 0.5P_{i-1}$,

this leads to the following solutions: $P_i = {}^{i}/_{N}$ and $E_i = i(N - i)$

QUESTION:

Nira plays the game starting with £4 and his goal is to win £10.

a) Calculate the probability that he loses i.e. ends up with £0.

b) Prove that the expected game duration would be a maximum if i = £5.

Answers:

a) All probabilities add up to 1. Therefore,

$P_{lose} = 1 - {}^{i}/_{N}$

$P_{lose} = 1 - {}^{4}/_{10} = 0.6$

b) E_i is a maximum when

${}^{dE_i}/_{di} = N - 2i = 0$.

$\rightarrow i = {}^{N}/_{2}$

$\rightarrow i = {}^{10}/_{2} = 5$

Peter Landin (1930 – 2009)

LGBTQ computer scientist and activist

Queen Mary University of London

"Most papers in computer science describe how their author learned what someone else already knew."

Peter Landin was a pioneering British computer scientist whose work in the 1960s laid critical foundations for the development of programming languages. Known for his contributions to the theory of programming languages, Landin introduced key concepts such as the SECD machine, the first abstract machine for lambda calculus, and coined the term "syntactic sugar." His innovative ideas greatly influenced the design and implementation of many modern programming languages, cementing his legacy as a visionary in the field of computer science.

Aside from his work as a computer programmer, Landin was also an active campaigner for LGBT rights and was a member of the Gay Liberation Front during the 1970's, following the separation from his wife in 1973. Landin's distancing from computer science was triggered by his belief that computer science has become a capitalist idea focused on profit taking and was ashamed by its move away from innovation.

Peter Landin aimed to create a programming language that was not limited to a single machine but could be used across various machines and manufacturers. To achieve this, he employed lambda calculus as the foundation for a new language. By utilizing lambda calculus, he integrated it into his own language, ISWIM, which featured higher-order functions, automatic storage management, and abstract syntax notation. ISWIM influenced the development of languages like LISP, ML, and Haskell. Landin's work also led to the introduction of 'Landin's Off-side Rule', an indentation rule commonly used in Python. This rule was detailed in his paper, 'The Next 700 Programming Languages', and is crucial for maintaining code structure and scope.

"There's a good part of computer science that's like Magic"

Landin's legacy is contained in the archives in the Bodleian Library in the University of Oxford. There is also an annual seminar entitled the *'Annual Peter Landin Semantics. Seminar'* as well as the Peter Landin building. home to the computer science department at Queen Mary University of London where he worked.

Scan to read an article

Landin's groundbreaking work in programming languages and semantics revolutionised how code is executed and structured, laying the foundation for modern programming practices.

Peter Landin (1930 – 2009)

LGBTQ computer scientist and activist

"If You See What I Mean" (ISWIM) and Syntactic Sugar

Landin fathered **ISWIM**, a family of programming languages which served as the mathematical design template for future languages such as Python, Rust, and many more.

ISWIM was based off λ calculus and emphasized separating a code's syntax (rules/procedure) from its semantics (behaviour).

In ISWIM, a definition like

$\boldsymbol{f(x) = x + 1}$

is ***SYNTACTIC SUGAR*** for a λ-calculus function:

$\boldsymbol{f \equiv \lambda x.(x + 1)}$

A.K.A. writing code in a prettier way!

QUESTION:

An ISWIM function is defined

$f(x, y) = x^2 + y^2$

Write this in λ calculus form and evaluate f(3,4)

ANSWER:

$\boldsymbol{f = \lambda x.\lambda y.(x^2 + y^2)}$

The "$\lambda x.\lambda y.(\ )$" part of the function is what tells ISWIM that f is a function of parameters x and y.

$f(3,4)$

$f \equiv \lambda x.\lambda y.(x^2 + y^2)$ [x=3, y=4]

$= (\lambda y.3^2 + y^2)$ [y=4]

= 25

Note how in this working x = 3 is substituted before y = 4. This is to show how in ISWIM, multi argument functions are computed as chains of single-argument ones.

Read Landin's paper *'The Next 700 Programming Languages'.*

The ENIAC Six

Queen Mary University of London

Successfully programmed the world's first modern computer

"We were making history, though we didn't realize it at the time." - Frances Bilas Spence

"None of us had any idea that what we were doing was pioneering anything. We were just doing a job." – Kathleen McNulty

During an era when the term "computer" referred to a job title rather than a machine, six women: Jean Jennings Bartik, Frances "Betty" Snyder Holberton, Kathleen "Kay" McNulty Mauchly Antonelli, Marilyn Wescoff Meltzer, Ruth Lichterman Teitelbaum, and Frances Bilas Spence —transcended societal expectations to become the first programmers of the world's first modern computer, the ENIAC. They mastered the complex circuitry of the ENIAC but also laid the groundwork for modern programming. A testament to their determination and intellect. Their legacy continues to inspire generations of women in technology, showcasing the transformative power of diversity and inclusion in driving technological progress.

Until it was decommissioned in 1955, ENIAC was used in the nuclear fission calculations and weather simulations required to create the hydrogen bomb.

<u>What was the ENIAC?</u>

Electronic Numerical Integrator and Computer, the world's first general-purpose, digital computer. It was developed during World War II by the United States Army to compute artillery firing tables with speed and accuracy. The programming of this computer involved manual setting switches and adjusting cables on a switchboard.

'Hidden Figures' - individuals whose significant contributions to a field were not widely recognised or acknowledged at the time, due to societal biases. These individuals played crucial roles in important milestones but remained invisible in historical narratives

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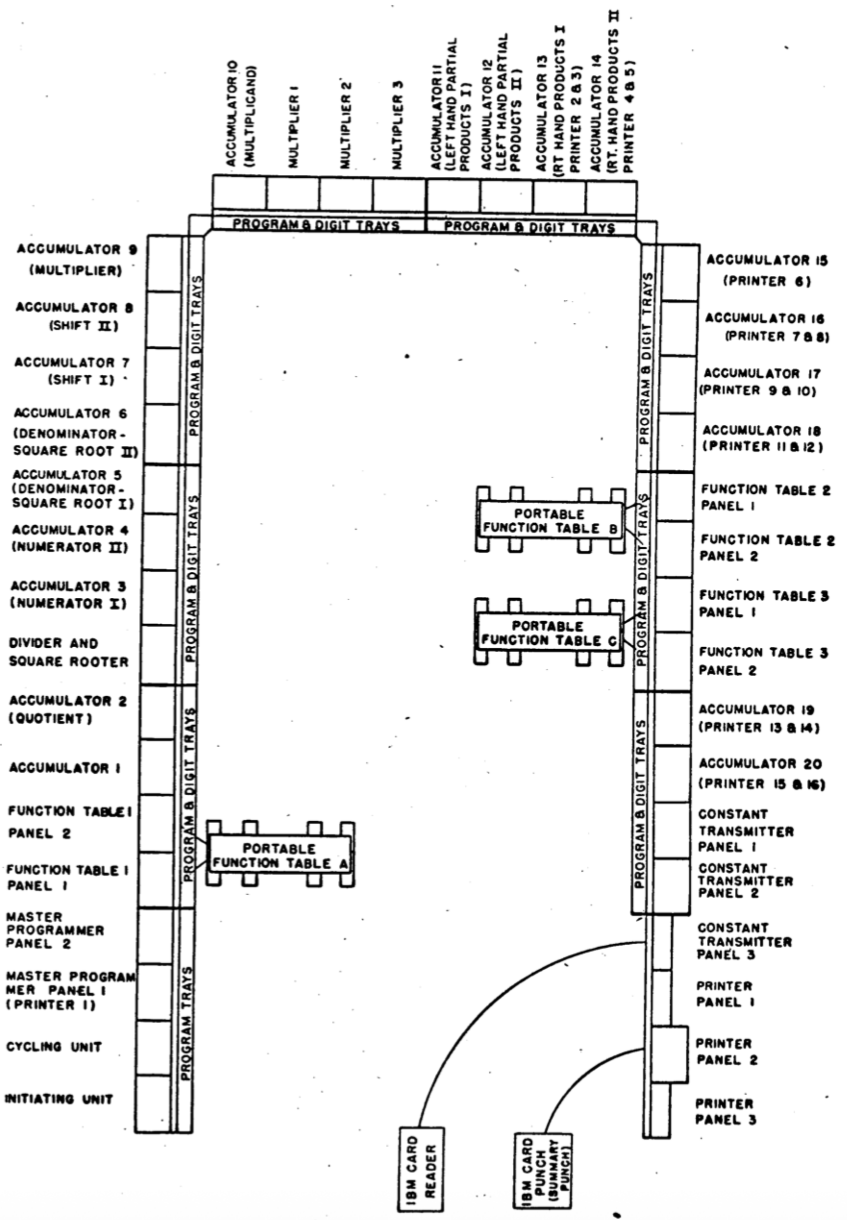
The credit for programming the ENIAC initially went to its male creators, John W. Mauchly and J. Presper Eckert, and their associates. In photos, members of the group were labelled as models opposed to their actual job role, i.e. programmers.

The ENIAC Six

Successfully programmed the world's first modern computer

Queen Mary University of London

The ENIAC's Computing Capabilities



Operation	Time Required, Microseconds	Speed, Operations Per Second
Addition or subtraction	200	5,000
Multiplication of two 10-digit numbers	2,800	360
Calling up of the value of a function (from function table)	1,000	1,000

The floor plan of the ENIAC - it took up a whole room!

The ENIAC boasted 20 accumulators and 3 multipliers enabling it to preform addition and multiplication calculations at high speeds. Function tables were also an important part of the computer, as they held mathematical constants and look-up tables of numbers. Each function table contained 1200 switches, which makes the ENIAC six's manual plugboard wiring even more impressive!

Consider the Mathieu differential equation shown below:

$$\frac{d^2y}{dt^2} + \epsilon(1 + k\cos(t))y = 0,$$

where, ϵ and k are parameters.

Solving for $\epsilon = 1,2,3,\ldots,10$ and $k = 0.1,0.2,0.3,\ldots,1.0$ produces 100 results which can be held in a y versus t table. Each result is solved by a corresponding difference equation. If $\Delta t = 0.0004$ and $0 < t < \pi$, 7850000 multiplications would be needed to calculate all 100 solutions.

QUESTION: How many minutes would it roughly take the ENIAC to compute all these multiplications? *(Hint: look at the table above)*

Answer: $7850000 \text{ multiplications } \div 360 \text{ operations per second} = 21805.56\text{ s}$

$$21805.56\ldots \times {}^{1}/_{60} = 363 \text{ minutes and } 26 \text{ seconds}$$