

# CAREERS THROUGH MATHS: MACHINE LEARNING ENGINEER



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## JOB DESCRIPTION

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A Machine Learning (ML) Engineer is a specialised software engineer who designs, builds, and deploys intelligent systems that can learn from data and make predictions or decisions autonomously. Their daily work is a blend of software development, data science, and rigorous mathematical application. They are responsible for the end-to-end ML lifecycle, which includes collaborating with data scientists to understand model requirements, writing robust and scalable code to train models, and deploying these models into production environments where they can deliver real-world value. For example, an ML Engineer at a fintech company like Monzo or Revolut might work on deploying a fraud detection model that must process millions of transactions in real-time, requiring a deep understanding of both the algorithm's mathematics and the software infrastructure it runs on.

The work environment is typically collaborative and fast-paced, often within cross-functional teams in sectors such as finance, healthcare, e-commerce, and research. An ML Engineer at the Alan Turing Institute, the UK's national institute for data science and artificial intelligence, might work alongside academic researchers and government bodies to develop models for public good, such as optimising NHS patient flow or analysing climate data. Their key duties include data preprocessing and pipeline creation, feature engineering, model selection and training, performance evaluation, and continuous monitoring and maintenance of live systems. This requires constant iteration and refinement based on new data and performance metrics.

Mathematics is the absolute cornerstone of this role. It is not merely a helpful skill but the fundamental language used to conceptualise problems, formulate solutions, and validate results. Every stage of developing an ML model is underpinned by mathematical principles. From the calculus used to optimise a model during training to the linear algebra that powers the manipulation of vast datasets, mathematics provides the toolkit for turning abstract concepts into functional, high-performance software. The ability to think mathematically is essential for diagnosing why a model is underperforming, for understanding the trade-offs between different algorithms, and for ensuring that the deployed system is both efficient and reliable.

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## HOW MATHEMATICS IS USED

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- **Linear Algebra:** This is the primary mathematical framework for handling multi-dimensional data. Vectors, matrices, and tensors are the fundamental data structures in ML. For instance, a recommendation system for a UK retailer like ASOS represents each customer and each product as high-dimensional vectors. The mathematical operation of calculating the dot product between a user vector and an item vector determines the predicted affinity, enabling personalised product suggestions. Similarly, image processing for a company like Babylon Health, which uses AI for medical imaging analysis, relies on representing images as matrices of pixel values. Convolutional Neural Networks (CNNs), which are essential for this task, perform operations like convolution and pooling that are entirely based on linear algebra.
- **Calculus (particularly Multivariable Calculus and Optimisation):** Calculus is crucial for the 'learning' process itself. ML models learn by iteratively adjusting their internal parameters to minimise a 'loss function' – a mathematical measure of the model's error. This optimisation is achieved using gradient-based methods like Gradient Descent. For example, when training a model to predict energy demand for the National Grid, an ML Engineer uses partial derivatives to calculate the gradient of the loss function with respect to each model parameter. This indicates the direction and magnitude of adjustments needed to reduce prediction error, ensuring the model becomes more accurate over time.
- **Probability and Statistics:** These areas are vital for making sense of data and quantifying uncertainty. ML Engineers use probability distributions to model real-world phenomena and statistical tests to validate their models. A credit scoring

model used by a UK bank like Lloyds Banking Group doesn't just output a 'yes' or 'no'; it calculates a probability of default. This probabilistic output allows for more nuanced risk assessment. Furthermore, statistical methods like hypothesis testing (e.g., A/B testing) are used to compare the performance of a new model against an existing one before a full rollout on a platform like BBC iPlayer to ensure the change actually improves user engagement.

- **Algorithms and Complexity:** Understanding the computational efficiency and scalability of algorithms is essential. ML Engineers must choose algorithms whose time and space complexity are suitable for the problem and data volume. For a large-scale project at a company like DeepMind, which deals with enormous datasets for protein folding prediction (AlphaFold), selecting an algorithm with quadratic time complexity ( $O(n^2)$ ) over a linear one ( $O(n)$ ) could make the difference between a computation that takes days versus one that takes years. This mathematical analysis is key to building practical and deployable systems.
- **Statistical and Analytical Methods:** Mathematical modelling is at the heart of translating business problems into ML tasks. This involves defining the objective function, selecting appropriate evaluation metrics (like precision, recall, or F1-score), and performing rigorous data analysis. In the UK's autonomous vehicle sector, for instance, companies like Wayve use complex mathematical models to simulate driving scenarios and train their AI. Analysing the model's performance across thousands of simulated journeys requires a deep statistical understanding to ensure the vehicle's decisions are safe and reliable before real-world testing.

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## KEY SKILLS & TOOLS

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Skill/Tool	Application
Python & ML Libraries (e.g., PyTorch, TensorFlow, Scikit-learn)	Python is the lingua franca for ML in the UK. Engineers use libraries like PyTorch (developed by Meta but heavily used in UK academia and industry) to build neural networks. This involves mathematically defining layers (linear algebra), loss functions (calculus), and optimisers to train models for tasks such as natural language processing for a UK-based company like Faculty AI.

Cloud Platforms (e.g., AWS, Google Cloud, Microsoft Azure)	ML Engineers use cloud services to manage the computational workload of training complex models. This involves mathematically provisioning the right amount of computing power (e.g., GPUs for parallel matrix operations) and storage, and scaling these resources efficiently to control costs, a key consideration for startups in London's Tech City.
SQL & Big Data Tools (e.g., Apache Spark)	Extracting and transforming data from large databases is a fundamental task. SQL queries are used to perform aggregations and joins, which are set-based mathematical operations. For handling petabyte-scale data, tools like Spark are used to perform distributed linear algebra operations across clusters of computers, a common practice at data-intensive organisations like the UK's Office for National Statistics.
Software Engineering & MLOps Tools (e.g., Git, Docker, Kubernetes)	Beyond pure mathematics, ML Engineers apply engineering principles to build reproducible and reliable systems. They use version control (Git) for code, containerisation (Docker) to create consistent environments, and orchestration (Kubernetes) to manage the deployment and scaling of multiple model instances, ensuring mathematical consistency across different environments.
Data Visualisation (e.g., Matplotlib, Seaborn, Tableau)	Communicating complex mathematical results to non-technical stakeholders is critical. Engineers use these tools to create clear visualisations of model performance metrics, data distributions, and feature importance. For example, creating a dashboard for NHS Trust managers to show how a patient readmission prediction model performs across different demographics.
Model Validation & Testing Frameworks	Rigorous mathematical testing is applied to ensure model quality. This includes using techniques like k-fold cross-validation to get robust estimates of model performance and implementing statistical tests to check for data drift in production models, a key requirement in regulated UK industries like finance and insurance.

**Typical Pathway:** The pathway typically begins with a strong mathematical foundation at A-level, with Mathematics and Further Mathematics being highly advantageous. The most common route is a bachelor's degree in a highly mathematical subject such as Computer Science, Mathematics, Physics, or Engineering from a UK university. Many aspiring ML Engineers then pursue a specialised Master's or PhD in Machine Learning, Artificial Intelligence, or Data

Science from institutions like Imperial College London, University College London (UCL), or the University of Edinburgh. Entry-level positions may include Junior ML Engineer or Data Scientist. Career progression can lead to Senior ML Engineer, ML Architect, or Head of Machine Learning within UK companies ranging from large banks (HSBC, Barclays) and consultancies (Deloitte, PwC) to innovative tech firms (DeepMind, Graphcore). Professional development often involves obtaining certifications from cloud providers (e.g., AWS Certified Machine Learning – Specialty) and engaging with the UK's vibrant tech community through meetups and conferences.

**Industry Demand:** The demand for Machine Learning Engineers in the UK is exceptionally high and continues to grow rapidly. According to reports from Tech Nation and the UK government's Digital Strategy, AI and machine learning are identified as critical skills for the future economy. The proliferation of data across sectors like finance, healthcare, retail, and cybersecurity is driving this demand, with companies investing heavily in AI to gain a competitive edge. This creates a significant talent shortage, making it a lucrative and secure career path for those with the requisite mathematical and technical skills.

**Real-World Impact:** Machine Learning Engineers in the UK are at the forefront of solving some of society's biggest challenges. Their work powers the fraud detection systems that protect millions of banking customers, enables the development of new drugs through advanced bioinformatics, and helps optimise renewable energy grids to combat climate change. The success of UK-based companies like DeepMind, whose AlphaFold project has made groundbreaking contributions to biological science, is a testament to the global impact of this profession. By applying advanced mathematics, ML Engineers not only drive economic growth but also contribute to advancements that improve public services, healthcare outcomes, and scientific discovery.