

CAREERS THROUGH MATHS: ELECTRICAL ENGINEER



JOB DESCRIPTION

Electrical Engineers in the UK are responsible for designing, developing, and maintaining a vast array of electrical systems and components. Their work is fundamental to modern life, from the power generation that lights our homes to the complex electronics in our smartphones. A typical day can involve a mix of computer-aided design (CAD), project management meetings, laboratory testing, and on-site inspections. For instance, an engineer at a firm like Rolls-Royce might design the electrical power systems for a new jet engine, while an engineer at National Grid could be planning the integration of a new offshore wind farm into the national transmission network. The work environment is equally varied, split between office settings, research laboratories, and industrial or construction sites, often requiring collaboration with other engineers, technicians, and clients.

The core duties are deeply analytical and require a rigorous approach. These include analysing technical specifications, creating detailed design schematics using specialised software, calculating system requirements (such as load capacities and fault currents), and selecting appropriate materials and components. A key part of the role is ensuring that all designs and installations comply with stringent UK health and safety regulations and British Standards (BS) or international equivalents. For example, when designing the electrical layout for a new residential development in London, an engineer must meticulously calculate cable sizes, protective device ratings, and earthing arrangements to ensure safety and compliance with the IET Wiring Regulations (BS 7671).

Mathematics is the universal language that underpins every aspect of this role. It is not merely a tool but the very foundation upon which safe, efficient, and innovative electrical engineering is built. Whether using calculus to model the transient response of a circuit to a sudden surge, applying complex numbers to analyse alternating current (AC) power flow, or employing statistics to predict component failure rates, mathematical proficiency is non-negotiable. The ability to translate a real-world problem into a mathematical model, solve it, and interpret the results is what distinguishes a competent engineer. This mathematical rigour ensures that projects from Scottish Power's grid upgrades to Jaguar Land Rover's electric vehicle development are both feasible and reliable.

HOW MATHEMATICS IS USED

- **Calculus (Differential and Integral):** This is fundamental for analysing how electrical systems change over time. Differential equations are used to model the behaviour of dynamic systems, such as the charging and discharging of capacitors in a timing circuit or the transient stability of the National Grid following a fault. Integral calculus is used to calculate the total energy consumed by a device over a period (the integral of power with respect to time), which is essential for billing and efficiency analysis. For instance, an engineer at Siemens designing a variable-speed drive for an industrial motor would use calculus to model the motor's acceleration and deceleration profiles, ensuring smooth operation and preventing damage.
- **Complex Numbers and Algebra:** The analysis of AC circuits, which form the backbone of the UK's power distribution, relies heavily on complex numbers. Quantities like impedance, voltage, and current are treated as complex numbers (phasors) to simplify calculations involving phase differences. This allows engineers to easily calculate power losses in overhead lines or determine the correct capacitor bank size needed to improve the power factor of a large factory, thereby reducing its electricity costs and easing the load on the grid. Linear algebra is also crucial for solving large systems of equations that arise in complex circuit analysis and signal processing.
- **Fourier Analysis:** This mathematical tool is essential for understanding non-sinusoidal waveforms, which are common in modern electronics due to devices like inverters and switched-mode power supplies. Fourier analysis allows

engineers to decompose a complex signal into its constituent sine waves. This is critical for designing filters that suppress electrical noise, ensuring compliance with electromagnetic compatibility (EMC) regulations set by UK bodies. For example, an engineer at ARM Holdings designing a microprocessor must use Fourier analysis to manage clock signal harmonics and prevent interference with other components.

- **Vector Calculus and Electromagnetism:** The core principles of electrical engineering—Maxwell's equations—are expressed using vector calculus. This area of mathematics is used to model electromagnetic fields. This is vital for designing electric motors and generators, antennas for telecommunications (e.g., for 5G networks being rolled out by BT/EE), and for predicting electromagnetic interference between systems. When planning the layout of high-voltage cables under a city like Manchester, engineers use these principles to calculate the magnetic fields produced and ensure they are within safe public exposure limits.
- **Statistical and Analytical Methods:** Electrical engineers use probability and statistics for reliability engineering and quality control. They analyse failure data to predict the mean time between failures (MTBF) for critical components, informing maintenance schedules for assets like London Underground's signalling systems. Statistical process control (SPC) is used in manufacturing to monitor the production of electronic components, ensuring consistency. Furthermore, data analysis and mathematical modelling are used to optimise the performance of the UK's smart grid, forecasting electricity demand based on historical data and weather patterns to balance supply from renewable sources like wind and solar.

KEY SKILLS & TOOLS

Skill/Tool	Application
Computer-Aided Design (CAD) Software (e.g., AutoCAD Electrical, EPLAN)	Used to create precise schematic diagrams and wiring layouts. The software performs mathematical checks for errors and can automatically generate bills of materials. For example, used by a building services engineer to design the

	lighting and power systems for the new HS2 railway stations, ensuring all circuits are correctly sized and protected.
Mathematical Modelling Software (e.g., MATLAB/Simulink, SPICE)	These are industry-standard tools for simulating and analysing electrical systems without building physical prototypes. An engineer at Dyson might use Simulink to model the entire control system for a new robotic vacuum, solving complex differential equations in real-time to optimise battery life and motor performance.
Data Analysis Tools (e.g., Python with Pandas/NumPy, Excel)	Used for processing and visualising test data. For instance, after conducting thermal tests on a new transformer for the National Grid, an engineer would use these tools to perform regression analysis on the temperature data to validate the design's cooling performance against mathematical models.
Programming Languages (e.g., C++, Python, VHDL)	Used for embedded systems and digital logic design. C++ might be used to program a microcontroller that manages battery charging in an electric vehicle. VHDL is used to describe the mathematical logic of digital circuits, such as those in FPGA chips designed by companies like Xilinx.
Specialised Test & Measurement Equipment (Oscilloscopes, Spectrum Analysers)	These tools capture real-world electrical signals. Engineers then apply mathematical analysis (e.g., calculating frequency, amplitude, rise time) to diagnose faults, measure performance, and verify that a product, such as a medical device, meets the specifications required for UKCA marking.
Technical Communication & Reporting	The ability to present complex mathematical findings clearly is crucial. This involves writing detailed reports for clients or regulatory bodies like the Office of Gas and Electricity Markets (Ofgem), and creating visualisations (graphs, charts) to explain technical trade-offs to non-engineers in a project management team.
Quality & Standards Compliance (e.g., ISO 9001, BS 7671)	Applying statistical methods for quality assurance and a rigorous understanding of the mathematical principles underpinning British Standards. This ensures that every design calculation, from cable current-carrying capacity to earth fault loop impedance, is accurate and verifiable for safety audits.

Typical Pathway: The most direct route begins with strong GCSEs (or Scottish Nationals) in Mathematics and Physics, followed by A-levels (or Scottish Highers) in these subjects, often supplemented by Further Mathematics. The next step is a Bachelor of Engineering (BEng) or a more comprehensive Master of Engineering (MEng) degree accredited by the Institution of Engineering and Technology (IET). Graduates typically start as a Graduate Engineer, working under the supervision of a Chartered Engineer. To achieve the highly respected Chartered Engineer (CEng) status, one must demonstrate competence through a period of initial professional development (typically 4-5 years) and pass a professional review with the IET. Career progression can lead to roles such as Senior Engineer, Principal Engineer, Project Manager, or Technical Director within UK companies like BAE Systems, Centrica, or Network Rail.

Industry Demand: The demand for Electrical Engineers in the UK remains strong, driven by major national initiatives such as the transition to net-zero carbon emissions, which requires massive investment in renewable energy, smart grids, and electric vehicle infrastructure. The UK government's commitment to infrastructure projects like HS2 and the expansion of broadband and 5G networks also fuels demand. According to the Office for National Statistics (ONS), roles in engineering are consistently listed among the sectors with skills shortages, indicating excellent job prospects for qualified candidates.

Real-World Impact: Electrical Engineers are at the forefront of solving some of the UK's biggest challenges. They are designing the offshore wind farms in the North Sea that are decarbonising the UK's energy supply, developing the communication systems that keep the country connected, and creating the advanced medical imaging equipment used in the NHS. Their mathematical work ensures the safety, reliability, and efficiency of critical national infrastructure, from the power sockets in our homes to the complex systems that drive the UK's economic growth and technological innovation.