

CAREERS THROUGH MATHS: CHEMICAL ENGINEER



JOB DESCRIPTION

Chemical Engineers in the UK are at the forefront of transforming raw materials into essential products in a safe, sustainable, and economically viable way. Their work is fundamental to major UK industries, including pharmaceuticals, energy, food and drink, and specialty chemicals. A typical day might involve designing a new process for a pharmaceutical company like AstraZeneca or GSK to manufacture a life-saving drug, optimising energy consumption at an oil refinery operated by Shell or BP, or scaling up the production of a new bio-plastic from a laboratory bench to a full-scale manufacturing plant for a firm like Croda International. Their work environment is diverse, ranging from office-based design and simulation work to on-site roles in manufacturing plants and refineries across the UK, from the chemical hubs in the Humber and Teesside to the pharmaceutical clusters in the South East and North West.

The core duties of a Chemical Engineer revolve around process design, operation, and improvement. This includes conducting risk assessments (using methods like HAZOP), specifying equipment like reactors and distillation columns, and ensuring processes comply with stringent UK health, safety, and environmental regulations set by bodies like the Health and Safety Executive (HSE) and the Environment Agency. They are responsible for troubleshooting plant operations to minimise downtime and maximise yield, directly impacting a company's profitability and efficiency.

Mathematics is the universal language of this role. It is central to every decision, from the initial concept to the final product. Chemical Engineers use mathematical models

to describe the physical and chemical changes occurring in a process. For instance, they apply calculus to model the rate of a chemical reaction in a reactor, or use fluid dynamics equations to ensure a new formulation can be pumped efficiently through pipes at a Unilever factory. Without a strong mathematical foundation, designing safe, efficient, and cost-effective processes would be impossible.

HOW MATHEMATICS IS USED

- **Differential Equations and Calculus:** This is the primary tool for modelling dynamic changes within processes. Chemical engineers use differential equations to describe how variables like temperature, pressure, and concentration change over time and space. For example, they solve heat transfer equations to design a heat exchanger that will efficiently cool a product stream in a Scottish whisky distillery. They also use calculus to determine the optimal reactor size and operating conditions for a new drug synthesis, maximising yield while minimising costly raw material use for a company like GSK.
- **Linear Algebra and Numerical Methods:** Real-world processes are often too complex for simple analytical solutions. Chemical engineers use linear algebra to solve systems of equations that represent mass and energy balances for an entire chemical plant. Numerical methods are then employed, using software to find approximate solutions for these complex models. For instance, they might use iterative numerical techniques to simulate the distillation of crude oil into its components (petrol, diesel, etc.) at a refinery like those in Fife or Pembrokeshire, predicting the purity of each output stream.
- **Statistics and Process Control:** Ensuring consistent product quality is paramount. Chemical engineers use statistical process control (SPC) to monitor production data, identifying trends and variations that could indicate a problem. They design control systems using statistical algorithms (like PID controllers) to automatically adjust process variables. For example, they might analyse data from a continuous food production line at a Nestlé factory to ensure every batch of chocolate meets exact taste and texture specifications, using regression analysis to correlate process parameters with final product quality.
- **Fluid Mechanics and Thermodynamics:** The principles of fluid flow and energy transfer are deeply mathematical. Engineers use the Navier-Stokes equations to

model fluid flow through pipelines and processing equipment, ensuring efficient transport and mixing. Thermodynamic calculations are essential for determining energy requirements, such as calculating the compressor power needed to transport natural gas through the UK's National Transmission System or designing the refrigeration cycle for a large-scale frozen food facility.

- **Optimisation Techniques:** A key goal is to maximise profit, minimise environmental impact, or reduce energy use. Chemical engineers use mathematical optimisation techniques (linear and non-linear programming) to find the best operating conditions. For example, they might develop a model to optimise the energy integration across a large chemical complex on Teesside, minimising fuel costs and CO₂ emissions by maximising heat recovery between different processes.

KEY SKILLS & TOOLS

Skill/Tool	Application
Process Simulation Software (e.g., Aspen HYSYS, Aspen Plus)	Used for designing and simulating entire chemical processes. Engineers mathematically model unit operations (reactors, separators) to predict plant performance, energy consumption, and economics before construction begins. For example, used by engineers at INEOS to design a new polymerisation process.
Mathematical Software (e.g., MATLAB, Python with NumPy/SciPy)	Employed for complex calculations, data analysis, and developing custom models. A chemical engineer might use Python to write a script that analyses years of production data from a Pfizer plant to identify the root cause of a yield reduction.
Computational Fluid Dynamics (CFD) Software (e.g., ANSYS Fluent)	Applies numerical analysis to solve complex fluid flow and heat transfer problems. Used to design the internal geometry of a chemical reactor for a company like Johnson Matthey to ensure optimal mixing and reaction efficiency.
	Essential for automating data processing, performing custom calculations, and linking different software tools. Used to create

Programming Languages (e.g., Python, VBA)	a bespoke tool for a water treatment company like Thames Water to optimise chemical dosing rates based on real-time water quality data.
Data Analysis & Statistical Packages (e.g., JMP, Minitab)	Critical for analysing experimental and plant data. Engineers use these tools to perform statistical tests, create control charts, and build empirical models to understand and improve process performance in UK manufacturing settings.
Technical Report Writing & Presentation Skills	The ability to clearly communicate complex mathematical findings and recommendations to colleagues, managers, and clients is vital. This includes writing detailed safety reports for the HSE or presenting a cost-benefit analysis for a new project to the board of a UK SME.
Process Hazard Analysis (PHA) Methodologies	While qualitative at heart, these methodologies (like HAZOP) rely on a systematic, logical (mathematical) approach to identify potential deviations from design intent in a process, ensuring compliance with UK COMAH (Control of Major Accident Hazards) regulations.

Typical Pathway: The standard pathway begins with strong GCSEs and A-levels (or Scottish Highers) in Mathematics, Chemistry, and Physics. Prospective engineers then complete a Bachelor's (BEng) or integrated Master's degree (MEng) in Chemical Engineering accredited by the Institution of Chemical Engineers (IChemE). Graduates typically enter the industry as a Process Engineer or Plant Engineer in sectors like oil & gas, pharmaceuticals, or consumer goods. To achieve the highly respected Chartered Engineer (CEng) status, they must undertake a period of Initial Professional Development (IPD) and pass a professional review with the IChemE. Career progression can lead to roles such as Senior Engineer, Project Manager, or Technical Director within UK companies and consultancies.

Industry Demand: The demand for Chemical Engineers in the UK remains robust, driven by the transition to a net-zero economy. The UK government's Industrial Strategy and the growth of sectors like sustainable energy (carbon capture, hydrogen, biofuels), advanced materials, and pharmaceuticals create significant opportunities. The Office for National Statistics (ONS) and reports from EngineeringUK highlight a sustained need for engineering skills, with chemical engineers being crucial for innovation in these high-growth areas.

Real-World Impact: Chemical Engineers in the UK have a profound impact on society and the economy. They were instrumental in the rapid scale-up of vaccine production during the COVID-19 pandemic. They are currently leading projects in carbon

capture and storage (CCS) in the Humber industrial cluster, directly contributing to the UK's climate targets. Their work ensures the safe and efficient production of everything from life-saving medicines and clean water to sustainable fuels and advanced materials, making them key players in the UK's industrial future.