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MATHS FOR ENGINEERING
Do T levels add up?

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Dr Mariam Makramalla, edited by Professor Chris Atkin CEng FREng FRAes and Johnny Rich

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#MathsForEngineering

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DO T LEVELS ADD UP?

FOREWORD

HOW well do T levels – the new vocational alternative to A levels – prepare students to study Engineering? Do they provide an adequate grounding in maths necessary to succeed? Is the mathematical content in an Engineering T level as good as a Maths A level? Or, given that it's learned in an applied setting, is it perhaps better?

These were some of the questions that the EPC set out to answer in an initiative prompted by discussions with the Department for Education, the Royal Academy of Engineering and the Engineering Council. The research has been conducted by **Dr Mariam Makramalla**, under the direction of a steering group chaired by **Professor Chris Atkin CEng FREng FRAes**.

Dr Makramalla's report provides a guide to what T levels are, the mathematical content you can expect a student to have covered, how that compares with A level Mathematics content, and in what contexts different level 3 qualifications provide the best foundation for studying Engineering. The aim is to better inform the admissions policies of engineering departments when it comes to making offers to T level students.

This report is the first in our Maths for Engineering project, which is generously **supported by Gatsby**. The project will go on to conduct a wider comparative study of the whole landscape of level 3 qualifications including A levels, Scottish Highers, the Welsh Baccalaureate, BTECs, the International Baccalaureate and so on. Those findings will be published later in 2024.

JOHNNY RICH
Chief Executive, Engineering Professors' Council

INTRODUCTION

THE EPC's Maths for Engineering project has been prompted by the current transition from BTECs (which are almost all being defunded) to T level qualifications.

In this report, we scope the coverage of Mathematics in T levels, both on a curricular and an assessment level. We present this following concerns raised regarding the Mathematics entry level requirements for Engineering higher education and in the hope of supporting a better informed approach to Engineering student admissions.

WHAT ARE T LEVELS?

INTENDED as an alternative route to A levels or the direct entry into apprenticeship-based jobs, T levels are a two-year programme that targets 16-19 year-old students. The T level programme is designed based on an interdisciplinary learning approach, in which sciences and mathematics are integrated in complex challenges that students must understand and tackle.

One T Level is intended to be equivalent to three A levels. Students interested in pursuing an engineering-oriented study programme can undertake one of the following specialisms:

- Onsite Construction
- Building Services Engineering
- Design & Development for Engineering & Manufacturing
- Maintenance, Installation & Repair
- Engineering, Manufacturing & Processing Control.

Additionally, students can also choose to concentrate on the following non-engineering specialisms:

- Management & Administration;
- Agriculture, Land Management & Production;
- Animal Care & Management (to be launched in Autumn 2024).

HOW ARE T LEVELS ASSESSED?

The assessment structure of T levels is made up of

EXAMS

Students sit **standardised closed book exams** in the following fields: (a) Paper 1: Maths & Sciences; and (b) Paper 2: Engineering Studies.

Written examinations are made available periodically at set assessment periods. Exams are assessed based on a pre-set rubric and are marked by a set of external examiners. A rigorous quality assurance process is administered, whereby exam papers are double-marked and cross-checked at several levels across the assessment committee.

PROJECTS

Students undertake **employer-set projects** that are composed of 4 main tasks; namely (a) a research task, (b) a reporting task, (c) a design task and (d) a presentation task.

Employer-set projects are made up of scenario-based challenges. Students analyse a given problem, research different solutions, report on their problem statement, conduct problem analysis and research solutions. Students also design a prototype of a gadget that is presented as a solution to the presented problem. Finally, students record a presentation outlining their problem-solving process.

The project-based assessment is centrally administered. **It is not conducted by the employers themselves.** The project-based assessment unit takes place over one practical assessment week, whereby clear milestones are outlined for each student. Research papers and reports that result from the practical assessment are assessed via a centralised unit of external assessors. The design task is either CAD-based or paper-based. It gets scanned and assessed according to a rubric that is predefined by a committee of external assessors. Student presentations are recorded and tthe recordings are also marked according to a pre-set rubric.

T LEVELS AND HIGHER EDUCATION ENTRY REQUIREMENTS

DISCUSSIONS with representatives of different higher education admissions stakeholders in the engineering field revealed that there are no set criteria for entry level mathematics. On the whole, the landscape of UK Engineering higher education admissions can be depicted as lying on a two-dimensional spectrum, as illustrated by the matrix in Figure 1 (below).

It is important to consider this matrix as a spectrum rather than a fixed structure. In other words, there is no engineering degree programme that would focus solely on skill development. Similarly, there is no degree that is purely theory-based. In the same way, the mathematics knowledge and skill entry requirements also need to be seen as lying on a spectrum that extends between firm and flexible criteria.

Based on this navigational framework, we have interviewed more than 20 stakeholders that have situated themselves in different quadrants of this spectrum. Those stakeholders adopted different views of T Level Mathematics for the purpose of admission to an engineering degree.

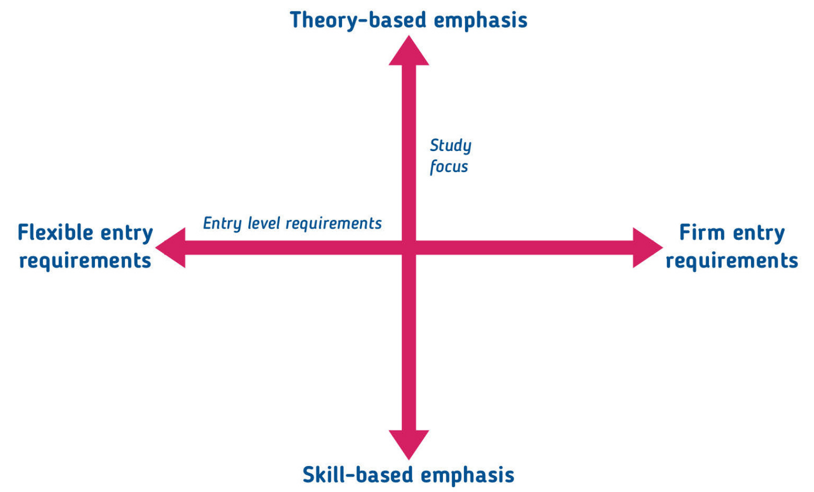

Figure 1. Spectrum of Engineering Higher Education Admission Landscape

ENTRY REQUIREMENTS IN ENGINEERING:

MATHEMATICS T LEVEL MAPPING

WE HAVE presented below the findings of a multi-stranded mapping process between Engineering higher education entry level requirements in Mathematics (across the spectrum in Figure 1 on page 3) and T Level Mathematics knowledge and skill sets. We distinguish between a mapping conducted at curricular level and mapping conducted at assessment level.

CURRICULAR CONTENT MAPPING

In this section, we focus solely on mapping the coverage of mathematics content in T levels when compared to Mathematics A levels. We map this against firm entry requirements of Engineering schools that could be classified as lying on the theory-oriented end of the concentration spectrum in Figure 1 (see Section 3).

Table 1 below presents a comparative account of the overarching content areas covered in T levels and expected at firm entry level theory-based engineering schools.

Table A (see Appendix) presents a detailed content area map that has been designed by admissions tutors at Leicester College. The detailed map presents a comparative account of learning outcomes across the two comparator qualifications (T levels and A levels). These are mapped against theory-based firm entry level requirements at Engineering departments (see Figure 1 on page 3). Academic staff acknowledge the presence of mathematical knowledge area gaps when mapping the content covered in A Levels compared to the content covered in T levels. Discussions with stakeholders in HE admissions revealed ongoing concerns regarding the level of content mathematical knowledge currently expected at the entry level of Engineering departments and whether this was practically applicable in the engineering industry today and therefore potentially less necessary as a requirement.

T Level Mathematics	A Level Mathematics	Firm entry level expectations
Number	Numerical methods	Numbers and complex numbers
Algebra	Algebra and coordinate geometry	Algebra and Cartesian geometry
Logs and exponentials	Exponentials and logarithms	Exponentials and logarithms
Sequences and series	Sequences and series	Sequences and series
Calculus	Differentiation and integration	Differentiation and integration
Functions (not covered)	Functions	Functions
Trigonometry	Trigonometry	Trigonometry
Vectors and matrices	Vectors	Matrices
Statistical analysis	Statistical sampling, data presentation and interpretation, probability, statistical distribution, statistical hypothesis and testing	Statistics

Table 1. Overarching mapping (see Appendix for further details)

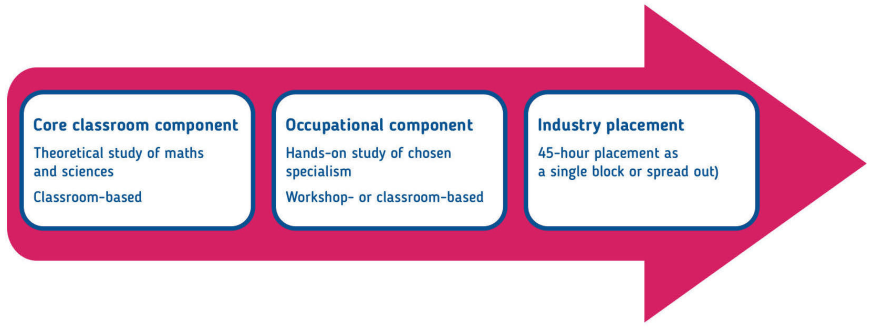

Figure 2. Three-level pedagogical component design of T Levels

CURRICULAR SKILLS MAPPING

T Level instruction happens over three different pedagogical components (see Figure 2 above); namely

- a core classroom-based component,
- an occupational component, and
- an industry placement component.

The first (core classroom) component is delivered in year 1. Students learn different concepts and theories relating to mathematics and sciences. Table 1 (see 'Curricular content mapping' on page 4) presents the overarching content areas covered in mathematics. The teaching adopts an interdisciplinary approach, whereby the teaching of Mathematics is blended with the applications in the sciences.

The second (occupational) component is based on the chosen student specialism (see specialisms in 'What are T levels?', page 2). Specialism-specific instruction takes place either in the classroom or in the designated workshop.

The third (industry placement) component requires students to complete 45 placement hours in the industry relevant to the specialism of choice. Students can complete the 45-hour placements in one block. Students could also choose to spread the required placement hours over the course of the two study years (subject to their arrangements offered by their provider and the employer).

Resulting from this three-level pedagogical design T level graduates are equipped with (1) complex problem-solving skills; (2) practical contextualised engineering skills, (3) communication skills, (4) interdisciplinary learning skills, (5) hands-on application skills and (6) critical thinking skills.

When mapping these skills against the entry requirements in the Engineering HE admissions, it becomes clear that Engineering departments (with firm or flexible entry requirements) that run a study programme which is more practice-oriented value students who have acquired the above entry level skill set. Theory-oriented Engineering departments, on the other hand, have one application-oriented entry requirement (Application of Mathematics), which may be screened during in-person interviews at entry level (if they conduct interviews). The entry level interview focuses on logical thinking and communication skills acquired by the applicant at entry level.

ASSESSMENT CONTENT MAPPING

The core classroom component (see Figure 2 on page 5) is assessed through a centrally governed standardised examination process. Sciences and Mathematics are tested in one examination and the chosen Engineering specialism is tested in a separate one. Students have the choice to complete their written assessment either at the end of the first or at the end of the second year.

Table 1 (page 4) shows the over-arching content areas that are assessed in the theoretical exam for Mathematics. Examinations are centrally designed and assessors mark each exam paper based on a given standard rubric.

ASSESSMENT SKILL MAPPING

The second component (occupational skills) is assessed through an externally drafted practical examination (see Figure 2 on page 5). The examination is challenge-based. It introduces the student to a scenario from their chosen specialism. Students need to use the knowledge and skills acquired to address different milestones of the challenge. The scenarios are also referred to as 'employer set projects'. They are not set by the employers themselves but are rather set by the awarding organisation.

Employer set projects extend over a limited time frame. There are four main tasks that a student needs to engage with throughout this practical assessment. These are: (1) a research task, (2) a reporting task, (3) a design task, and (4) a presentation task. In this way, the student goes through all stages of the Engineering Design Cycle to solve the problem at hand.

The employer set projects are externally assessed by a committee of examiners. Assessment is based on a given rubric. The examination committee is monitored by a hierarchy of examination assessors to ensure the quality and consistency of the assessment process across various employers.

CONCLUSION: WHAT SHOULD UNIVERSITIES DO?

DEPENDING on their positioning in the landscape matrix presented in Figure 1 (see page 3), Engineering departments are more/less likely to admit T level graduates. Based on interviews held with stakeholders, Table 2 below indicates potential responses from insitutions from across all parts of the matrix.

Positioning in landscape	Expected response	Recommendation
Theory-based focus with firm entry requirements	T Level Mathematics content may be deemed unsatisfactory. T level students have a lower prospect of admission to these institutions.	Interviews revealed that some institutions in this category would expect T level graduates to study A level Mathematics alongside their T Level Mathematics. This is not normally a feasible option. These institutions might consider collaborating with further education colleges to offer a 'bridging course' to T level graduates prior to entry into in Engineering high education (such as that offered by Leicester College, see Appendix).
Theory-based focus with flexible entry requirements	T level graduates are more likely to be suitable for admission.	Students are likely to follow a theoretical Mathematics course during their first year at university to ensure all students have the same foundational level of knowledge.
Practice-based focus with firm entry requirements	These Engineering departments tend to have adapted their admission criteria to focus more on an in-depth examination of student-acquired skill set and they report a higher than average likelihood of accepting T Level students.	Students are likely to follow a theoretical Mathematics course during their first year at university to ensure all students have the same foundational level of knowledge.
Practice-based focus with flexible entry requirements	T level graduates are likely to be suitable for admission without impediment.	Interviews with T Level students indicated that this type of Engineering department was their preferred choice for higher education. A practice-based approach aligns more closely with their T level experience. Flexible entry requirements should allow them to their options with a higher chance of admission.

Table 2. Higher education Engineering admission responses to T levels

APPENDIX

THE following is a curricular level mapping table that has been created by colleagues at **Leicester University**. The table presents the gaps in terms of content area coverage between T Levels and A Levels. **Leicester College** is currently in the process of designing a 'bridging course' that T level students could take, so that their T level students would be more directly equivalent to their A level counterparts when it comes to Mathematics.

COMPARISON OF MATHS IN ENGINEERING T-LEVEL / ACCESS TO HE / A-LEVEL

Subject	T levels Maths unit/topics	Access to HE (Additional Maths content)	A level Maths topics
Number	• Perform arithmetic operations on integers, decimal numbers and numbers in standard form using rules of arithmetical preference: brackets indices division multiplication adding and subtraction (BIDMAS). • Work to a specified number of decimal places or significant figures. • Carry out calculations using fractions, percentages, ratios and scale.	• Not on syllabus, content assumed	• I: Numerical methods
Algebra	• Simplify, factorise and manipulate equations to change the subject Solve simultaneous and quadratic equations. • Apply rules of indices. • Interpret and express changes in an engineering system from a graph (straight line, trigonometrical and exponential relationships). • Determine the equation of a straight line from a graph ($y=mx+c$).	• Polynomial division. Factor theorem. • Curve sketching. • Algebraic fractions. • Simultaneous equations with quadratics.	• B: Algebra and functions • C: Coordinate geometry in the (x,y) plane
Logs and Exponentials	• Apply laws of logarithms (base 10 and natural) – problem-solving including problems involving growth and decay.	• Exponential graphs. Log graphs and use of log graph paper.	• F: Exponentials and logarithms
Sequences and series	• Determine numbers in a sequence using arithmetic and geometric progression, power series.	• Binomial expansion up to and including negative powers. Pascal's Triangle. Limit of a sequence. Small value expansion.	• D: Sequences and series
Calculus	• Determine standard differentials and integrals (basic arithmetic operations, powers/indices, trigonometric functions). • Determine standard differentials and integrals (basic arithmetic operations, powers/indices, trigonometric functions). • Calculate maximum and minimum values in engineering contexts using differentiation.	• Differentiation: product, quotient, chain rule, implicit differentiation. • Integration: areas under a curve and between curves. Mean and RMS. Volumes of solids of revolution. • Integration by substitution, integration by parts. • Simple differential equations.	• G: Differentiation • H: Integration
Trigonometry	• Use of Pythagoras' theorem and triangle measurement. • Circular measure including conversion between radians and degrees. • Application of trigonometric functions (sin, cos, tan), their common values, rules and graphical representation. • Determining dimensions of a triangle using sine and cosine rules. • Common trigonometric identities (sec, csc, cot).	• Analysis of sine waves. Sketching trig waves. Trigonometric identities. Trig equations.	• E: Trigonometry
Statistics	• Calculation of range, cumulative frequency, averages (mean, median and mode) and standard deviation for statistical data in an engineering context. • Determination of probabilities in practical engineering situations.	• Statistical diagrams, including histograms, box and whisker, cumulative frequency curves. • Scatter diagrams, regression, and correlation. • Normal distribution. • Binomial distribution	• K: Statistical sampling • L: Data presentation and interpretation • M: Probability • N: Statistical distributions • O: Statistical hypothesis testing
Functions		• Equation of a circle, including tangent and normal. • Inverse functions. • Composite functions. • Transformation of graphs. • Parametric equations. • Modular functions.	• F: Exponentials and logarithms
Vectors and Matrices	• Addition, subtraction and multiplication of matrices in engineering context. Use of vectors including addition, dot and cross product	• Binomial expansion up to and including negative powers. Pascal's Triangle. Limit of a sequence. Small value expansion.	• J: Vectors

CONTRIBUTIONS

THE ENGINEERING PROFESSORS' COUNCIL MATHS FOR ENGINEERING ADVISORY GROUP was created to oversee this research. We would like to express our sincere thanks to the Advisory Group for their commitment, expertise and generosity with their time.

ADVISORY GROUP MEMBERSHIP

Chair: **Chris Atkin**, University of East Anglia and former Chair of the Engineering Council
Stylli Charalampous, Royal Academy of Engineering
Stella Fowler, Engineering Professors' Council
Dr Paul Greening, Coventry University
Prof Georgina Harris, Arden University
Prof Catherine Hobbs, University of Bristol
Dr Rachel Long, University of the West of England Bristol
Research Lead: **Dr Mariam Makramalla**, Engineering Professors' Council
Dr Rhys Morgan, Royal Academy of Engineering
Prof Abel Nyamapfene, University College London
Prof Geoff Parks, University of Cambridge
Johnny Rich, Engineering Professors' Council
Prof Colin Turner, University of Ulster

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Engineering Professors' Council, First Floor Office, 3 Hornton Place, London, W8 4LZ
T: +44 (0)7449 970472 ● E: info@epc.ac.uk ● @EngProfCouncil ● W: epc.ac.uk

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