# Engineering

# Unit 1 – Mathematics for Engineering

# Scheme of work

# (60 GLH)

## Introduction

This outline scheme of work (SOW) is to offer a perspective of how to deliver the Cambridge Technicals in Engineering. There are many alternatives methods and structures that could be used and therefore it is important to explore different methods of delivering the specification, considering different approaches depending on staffing and expertise within your centre and the resources you have available.

Consideration of how the **theoretical content** of the specification can be covered is best delivered in different ways, through:

* A variety of different teacher resources
* Stimulate discussions
* Group work
* Learner activities
* Variety of questions relating to all the different topics

Aiming for quality communication and professional standards of work will help to establish the connections between this qualification and real-world practice.

**Overview (by lesson, topic area and GLH)**

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|  | **Lesson** | **Topic Area** | **Suggested GLH** |
| **LO1** | 1 | Applications of algebra | 2 |
| 2 | Simplification of polynomials | 2 |
| 3 | Transposition of formulae | 2 |
| 4 | How to simplify and solve equations | 2 |
| 5 | Linear simultaneous equations | 2 |
| 6 | Quadratic equations | 2 |
| **LO2** | 7 | Co-ordinate geometry – straight lines | 2 |
| 8 | Curve sketching | 2 |
| 9 | Graphical transformations | 2 |
| **LO3** | 10 | Exponentials and logarithms | 2 |
| 11 | Inverse function and log laws | 2 |
| **LO4** | 12 | Angles and radians | 1 |
| 13 | Arcs, circles and sectors | 2 |
| 14 | Right-angled triangles | 3 |
| 15 | Other triangles | 3 |
| 16 | Common trigonometric identities | 2 |
| 17 | Sine, cosine and tangent operations | 2 |

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|  | **Lesson** | **Topic Area** | **Suggested GLH** |
| **LO5** | 18 | Differentiation – graphical methods and simple algebraic expressions | 2 |
| 19 | Differentiation of trigonometric functions | 2 |
| 20 | Differentiation of exponentials and logs | 2 |
| 21 | Differentiation – maxima and minima | 2 |
| 22 | Indefinite integration – simple algebraic functions | 2 |
| 23 | Indefinite integration – sine and cosine | 2 |
| 24 | Definite integrals | 2 |
| **LO6** | 25 | Histograms, frequency polygons and cumulative frequency curves | 2 |
| 26 | Problem solving for a set of data – mean, mode and median | 2 |
| 27 | Problem solving for a set of data – distribution, percentiles, quartiles and skew | 2 |
| 28 | Problem solving for a set of data – variance and standard deviation | 2 |
| 29 | Problem solving using probability | 2 |
| 30 | Addition and multiplication laws of probability | 1 |

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| **Lesson** | **Learning outcomes and topics** | **Unit content to be covered, activities, links to useful resources** |
| **Engineering Unit 1: Mathematics for Engineers** | | |
| 1 | LO1: Applications of algebra | Begin the unit with a refresher of common algebraic techniques learnt at GCSE including multiplication by a constant, binomial expressions, removing a common factor, factorisation and using a lowest common multiple (see exemplification in unit specification 1.1).  Use problems relevant to engineering where possible. Adopt a style throughout the unit of showing worked engineering examples and getting learners to solve many practice questions.  **Resources:** a useful book that will support most topic areas in this unit is ***“Basic Engineering Mathematics”*** by John Bird (ISBN-10: 1138673706). This book includes many practice questions, and online learner and teacher resources.  ***OCR Exam Builder*** which includes a complete database of previous exam questions and solutions will also prove useful for generating practice questions. |
| 2 | LO1: Simplification of polynomials | Develop worked examples and learner tasks for the simplification of polynomials by, factorising a cubic, algebraic division and the remainder and factor theorems.  Examples from the suggested book will prove useful. |
| 3 | LO1: Transposition of formulae | Transposition of formulae is a fundamental mathematical tool, and one which learners should understand well.  Show learners how to transpose formulae containing two like terms, roots and powers.  Use engineering examples where possible (e.g. transposition of fundamental engineering formulae or equations describing engineering laws and relationships). |
| 4 | LO1: How to simplify and solve equations | Develop further worked and practice examples to consolidate learner’s knowledge of the application of algebra, polynomials and transposition. See exemplification in unit specification 1.3. |

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| 5 | LO1: Linear simultaneous equations | Show learners how to solve linear simultaneous equations using both graphical and algebraic methods. Limit these to two unknowns.  Develop suitable worked and practice examples engineering examples such as current in electrical loops (Kirchhoff’s Laws), systems of mechanical forces, or system modelling using forces and pressures. See examples in unit specification exemplification 1.5.  **Resources:** see **Lesson Element** on linear simultaneous equations which includes engineering examples using Kirchhoff’s Laws and the SUVAT equations for a roller coaster |
| 6 | LO1: Quadratic equations | Show learners how to solve quadratic equations using graph sketching, factorising method, completing the squares and using the classical quadratic formula:  Use worked and practice examples as relevant to engineering problem solving. See unit specification exemplification 1.6 which includes bending moments, fabrication of steel boxes and the SUVAT equations.  **Resources:** Khan Academy (<https://www.khanacademy.org/>) includes videos, worksheets and interactive quizzes covering many topic areas in this unit. This includes solving quadratic equation using various methods. |
| 7 | LO2: Co-ordinate geometry – straight lines | Recap on GCSE mathematics with learners solving problems to determine the equation of a straight line between two points, gradient of a line, mid-point and distance between points.  Engineering examples include source vs displacement for linear spring and resistivity/Ohms Law. |
| 8 | LO2: Curve sketching | Curve sketching is a useful method to visualise and solve more complex mathematical formulae.  Show learners how to sketch and solve graphs of the form  y = kxn and cubic functions.  In addition to hand-sketching this might present an opportunity for learners to produce graphs using a spreadsheet which will develop their skills at solving problems using ICT. |
| 9 | LO2: Graphical transformations | Use suitable worked examples to demonstrate graphical transformations by addition and multiplication (i.e. stretches and reflections) which might relate to engineering problems, with learners solving practice problems.  See exemplifications in unit specification 2.1. |
| 10 | LO3: Exponentials and logarithms | Demonstrate how to manipulate and solve exponential growth and decay and logarithmic problems of the form:  y=eax, y=e-ax, ey = x and ln x = y  Develop worked engineering examples and learner tasks to develop understanding of the application of exponentials and logarithms such as voltage/current growth and decay in DC circuits with a capacitor. See exemplification in unit specification 3.1.  Leaners could sketch and interpret graphs showing exponential growth and decay. Graphs could be hand produced or produced using ICT. |
| 11 | LO3: Inverse function and log laws | Continue the topic area by showing learners how to solve and manipulate exponential functions by rearranging using logarithms.  Examples could include rearranging and solving RC circuit problems e.g. of the form:  by inverting the function and transposition to find a different subject.  Exemplification given in unit specification 3.2 is useful.  **Resources:** see **Lesson Element** on inverse function and log laws which includes engineering examples of a belt/pulley system and charging of a capacitor |
| 12 | LO4: Angles and radians | Begin the area of trigonometry by introducing learners to angles and radians. Learners could solve problems that require the conversion between angles and radians. Engineering examples might include problems involving rotating shafts and pulleys or alternating electrical waveforms. |
| 13 | LO4: Arcs, circles and sectors | Show learners how to solve engineering problems involving arcs, circles and sectors. This could include formula for length of an arc, formula for sector of a circle and use of the co-ordinate equation: (x – a)2 + (y – b)2 = r2.  Encourage learners to solve problems both numerically and to prove their solutions graphically using scaled sketches.  Engineering examples might include those that require the solution of component geometry (e.g. mating of components, layout of belts, pulleys and levers etc).  Unit specification exemplification 4.2 gives formulae for length of arc and area of sector. |
| 14 | LO4: Right-angled triangles | Show learners what is meant by the term “solution” of a triangle, Pythagoras’ Theorem, and use of sine, cosine and tangent rule for right-angled triangles. Introduce formulae for the area of a right-angled triangle.  Learners could solve problems both graphically (using scale sketches) and numerically for right-angled triangles.  Examples are shown in the unit specification exemplification 4.3. |
| 15 | LO4: Other triangles | Show learners how to apply the sine rule, cosine rule and how to determine lengths, angles and areas for non-right-angled triangles.  Worked examples and practice questions will be useful to develop learner’s understanding. |
| 16 | LO4: Common trigonometric identities | Develop problems where learners apply a range of common trig identities:  sin 60˚ = (√3)/2  cos 60˚ = ½  tan 60˚ = √3  tan 45˚ = 1  sin 45˚ = 1/√2  cos 45˚ = 1/√2  sin 30˚ = ½  cos 30˚ = (√3)/2  tan 30˚ = 1/√3  Solution could be determined numerically with scale sketches used to prove their correct solution.  Refer to unit specification 4.6 for further trig identifies  **Resources:** the MEI (Mathematics Education Innovation) website has many free resources dedicated to engineering mathematics at Level 3 (<https://mei.org.uk/free-resources>). These include contextualised engineering problems on topic areas in this unit, including trigonometry. |
| 17 | LO4: Sine, cosine and tangent operations | Show learners to interpret and produce graphs from sine, cosine and tangent functions (y = sin x, y = cos x and y = tan x for a range of angles from 0˚ to 360˚). Learners could also determine the sine, cosine and tangent of any angle between 0˚ and 360˚.  Encourage learners to sketch graphs manually or could use ICT to produce graphs and solve problems. |
| 18 | LO5: Differentiation – graphical methods and simple algebraic expressions | Split the delivery of differentiation into discrete areas.  Begin by introducing learners to graphical methods to solve differential problems, and to simple algebraic expressions (from specification 5.1)  Learners could practice solving problems to develop understanding.  **Resources:** the following website contains useful material to support differentiation, with tutorials, worked examples and practice questions: <http://www.met.reading.ac.uk/pplato2/index.html>  Khan Academy (<https://www.khanacademy.org/>) includes some excellent videos, worksheets and quizzes covering differentiation. |
| 19 | LO5: Differentiation of trigonometric functions | Continue differentiation by introducing common trigonometric functions:  y = sin.x  y = a.sin.x  y = a.sin.bx  y = cos.x  y = a.cos.x  y = a.cos.bx  y = a.cos.x + b.sin x, where “a” and “b” are constants  Use worked engineering examples and practice problems to develop understanding (see unit specification exemplification 5.1 for examples).  Graphical explanation could be used to help learners embed understanding of the differentiation of sine and cosine functions. |
| 20 | LO5: Differentiation of exponentials and logs | Solve problems of the form y=eax and y=ln ax  Problems could be solved numerically, and their solution proven using a sketch of the function to demonstrate understanding. |
| 21 | LO5: Differentiation – maxima and minima | Determination of turning points (maxima and minima) requires that the function is differentiated twice.  Develop worked examples showing how to determine maxima and minima.  Learners could solve practice problems with both numerical and graphical solution being used as appropriate. |
| 22 | LO5: Indefinite integration – simple algebraic functions | Introduce learners to integration through simple indefinite integrals of the form:  y = axn ... ∫ axn dx = (axn + 1)/ n + 1 + constant C  Use graphical methods to illustrate integration. This might prove a useful starting point to explain the purpose of integration.  Reinforce the need to include the constant C with indefinite integrals.  Show learners worked examples; encourage learners to solve many practice problems. See unit specification exemplification 5.2 for examples.  **Resources:** the following website contains useful material to support integration, with tutorials, worked examples and practice questions: <http://www.met.reading.ac.uk/pplato2/index.html>  Khan Academy (<https://www.khanacademy.org/>) includes some excellent videos, worksheets and quizzes covering integration. |

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| 23 | LO5: Indefinite integration – sine and cosine | Continue integration by introducing the integration of common trigonometric identities:  ∫ sin x dx = – cos x + C  ∫ cos x dx = sin x + C  ∫ sin ax dx = -cos ax/a + C  ∫ cos ax dx = sin ax/a + C  Show learners worked examples; encourage learners to solve practice problems. |
| 24 | LO5: Definite integrals | Conclude integration by introducing problems involving definite integrals (i.e. integration between defined limits).  Show the form and rules for a definite integral including notation:  a∫ b fx = [F(x)]ba = F(b) – F(a)  Refer to unit specification 5.3 for other forms of definite integral functions.  Develop worked and practice problems for learners to solve using definite integrals. |
| 25 | LO6: Histograms, frequency polygons and cumulative frequency curves | Begin the study of statistics with problems involving histograms, frequency polygons and cumulative frequency curves.  Use engineering examples to solve problems where possible. |
| 26 | LO6: Problem solving for a set of data – mean, mode and median | Show how to determine mean, mode and median from a set of data.  Develop suitable worked examples using sets of data – or task learners to gather real data relevant to engineering operations.  Engineering examples might include quality control of machined parts, or reliability of electrical and electronic components.  Problems could be solved numerically and with the aid of ICT to develop graphical solutions.  **Resources:** the Open University “Open Learn” website (<https://www.open.edu/openlearn/science-maths-technology/free-courses>) has many different self-contained short courses covering mathematics for technology. This includes courses on problem solving using data (mean, mode and median). |

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| 27 | LO6: Problem solving for a set of data – distribution, percentiles, quartiles and skew | Continue the analysis of data sets by introducing the concept of distribution of data including percentiles, quartiles and skew.  Refer to unit specification 6.3 for complete list of data operations.  Use suitable engineering examples such as the reliability of measurement data or analysis of manufacturing production rates. Learners may also be able to gather and analyse real data, for example, for measurement of component dimensions.  Show worked examples and provide practice problems for learners to work through. |
| 28 | LO6: Problem solving for a set of data – variance and standard deviation | Conclude the analysis of data by introducing variance and standard deviation. Similar engineering examples might be used – for example mechanical or electrical component tolerances.  Learners might research and explain the significance of variance and standard deviation in the context of quality control.  **Resources:** see **Lesson Element** on problem solving with data which covers standard deviation and variance |
| 29 | LO6: Problem solving using probability | Develop worked and practice problems for probability which are relevant to engineering. This should include expectation, dependent events without replacement and independent events with replacement.  Suitable engineering examples might include mechanical component and system reliability in terms of backup capacity, or likelihood of critical component failure in an electromechanical system |
| 30 | LO6: Addition and multiplication laws of probability | Conclude the topic area of probability by showing learners how to solve problems using the addition and multiplication law of probability.  Learners could apply these to solving engineering examples such as systems in which there are multiple dependent components each with their own reliability figure. |

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