Unit 19: Mathematics for Engineering Technicians

Unit code: A/600/0253

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners a strong foundation in mathematical skills. These skills will help them to successfully complete many of the other units within the qualification.

Unit introduction

Mathematics and engineering go hand in hand. It is essential that engineers have a sound practical understanding of the mathematics behind their subject. This unit will give learners the foundation on which to develop the mathematical skills required in an engineering environment. Mathematics can solve many engineering-related problems before any prototypes and/or physical components have been made. This can save time and money and is kinder to the environment.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use algebraic methods

2 Be able to use trigonometric methods and standard formula to determine areas

3 Be able to use statistical methods to display data

4 Be able to use elementary calculus techniques.

Unit content

1 Be able to use algebraic methods

Algebraic methods: eg transposition, substitution, manipulation, logarithms, laws of indices, quadratic formula, factorisation

2 Be able to use trigonometric methods and standard formula to determine areas

Use of trigonometric ratios: sine, cosine, tangent; solution of non-right angled triangles eg sine rule, cosine rule; use of standard formula eg area of circle, surface area of cylinder, surface area of cuboid; circle formula eg circumference, diameter, radius, angles expressed in radians; standard volume formula eg cylinder, cuboid, torus, sphere, spherical ended cylinder

3 Be able to use statistical methods to display data

Statistical information: eg arithmetic mean; median; mode; discrete and grouped data, frequency, range, minimum, maximum

4 Be able to use elementary calculus techniques

Theory of calculus: eg history of calculus, uses of calculus, functions f(x), limits; differential calculus: table of derivatives, differentiate simple equations; integral calculus: table of integrals, integrate simple equations; use of constants, rate of change, $\frac{dy}{dx}$

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 manipulate and simplify three algebraic expressions using the laws of indices and two using the laws of logarithms [IE, SM]	**M1** use algebra to manipulate formula with three unknown values into a new expression with one unknown	**D1** solve quadratic equations using the formula Method, factorisation method and graphically
P2 solve a linear equation by plotting a straight-line graph using experimental data and use it to deduce the gradient, intercept and equation of the line [EP, TW]		
P3 factorise by extraction and grouping of a common factor from expressions with two, three and four terms respectively [IE]		
P4 solve circular and triangular measurement problems involving the use of radian, sine, cosine and tangent functions [IE, SM]	**M2** use inverse functions of trigonometric ratios	
P5 sketch each of the three trigonometric functions over a complete cycle [CT]		
P6 produce answers to two practical engineering problems involving the sine and cosine rule [RL]		

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P7 use standard formulae to find surface areas and volumes of regular solids for three different examples respectively [IE SM]		
P8 collect data and produce statistical diagrams, histograms and frequency curves [EP TW]	**M3** use graphical means to extrapolate future trends based on historical values	**D2** use graphical means to accurately determine the minimum surface area of a given shape that has a fixed volume suggesting alternative shapes with reasons.
P9 determine the mean, median and mode for two statistical problems and explain the relevance of each average as a measure of central tendency [IE]		
P10 apply the basic rules of calculus arithmetic to solve three different types of function by differentiation and two different types of function by integration. [IE, CT, RL SM]	**M4** use calculus to accurately determine the minimum surface area of a given shape that has a fixed volume.	

PLTS: This summary references where applicable in the pass criteria, in the square brackets, the elements of the personal, learning and thinking skills. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

Delivery of this unit will involve practical open book examinations, assessments, written reports, visits to suitable collections and will link to industrial experience placements.

This unit would be best delivered at an early stage in the qualification. It should be linked with other technical units to demonstrate the practical application of mathematics within land-based technology.

Before starting the unit, learners should be able to demonstrate proficiency in basic mathematical concepts and in the use of an electronic scientific calculator to carry out a variety of functions.

It is essential for learner motivation that the unit content is delivered in a land- based vehicle context. Ideally, this will be achieved through integration with other units which will also help reduce the assessment burden on learners. There are natural links with other units in the qualification. For example, electrical units that use algebraic application of Ohm's law, measurements of resistance versus temperature for graphing purposes, units involving calculation of engine ratios and volumes or trigonometric applications related to steering and suspension.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan gives **an indication of the volume of learning it would take the average learner** to achieve the learning outcomes. It is **indicative and is one way of achieving the credit value.**

Learning time should address all learning (including assessment) relevant to the learning outcomes, regardless of where, when and how the learning has taken place.

Topic and suggested assignments/activities and/assessment
Introduction to the unit and familiarisation with the formulae that will be used.
Algebraic methods; manipulation of formulae, powers, laws of indices, logarithms.
Graphs investigate correlation between heat and resistance and plot the resultant graph. Work out intercept, gradient and the equation of the graph.
Quadratic methods of factorisation and formula and graph.
Assignment 1: Use of Engineering Equations (P1, P2, P3, M1, D1,) Questions relating to the grading criteria.
Trigonometry: right-angled triangles, trig., ratios; sine, cosine, tangent. Graphs of sine, cosine and tangent, non-right angled triangles, cosine rule and sine rule.
Circular measurements – use of radians.
Assignment 2 – Application of Engineering Mathematics. (P4, P5, P6, P7, M2) Use of triangles to calculate lengths of struts, braces etc, in buildings, volumes and surface areas of cylinders. What size hydraulic actuator would need to be used on a tele-handler to raise the boom to a height of X, using X litres of oil positioned X distance from fulcrum.

Topic and suggested assignments/activities and/assessment
Carry out survey into land-based sectors. ie field efficiencies, business sales trends, tyre pressures, tractor horsepower requirements.
Assignment 3: Engineering Statistics (P8, P9, M3) Report based on an investigative study into a land-based area of interest. Use the information to derive new connotations.
Calculus: introduction to topic, history of calculus, table of derivatives, differentiation, table of Integrals, integration.
Assignment 4:Calculus (P10, M4, D2) Use calculus to calculate the minimum surface area that a solid can have with a given volume. Prove calculus by using alternative methods to arrive at the answer ie trial and error, graphically.
Unit review.

Assessment

For P1, learners should demonstrate an understanding of formula manipulation, detailed answers including full workings will provide good evidence. Learners are also required to work with indices and logarithms.

For P2, learners will need to plot a graph from data that is directly observed or, if this is not possible, a sample may be provided. The data used to produce the graph should have a minimum of 50 readings. A completed graph and the associated table will serve as evidence along with the calculations to determine the gradient, intercept and equation of the graph.

P3 should also use land based vehicle-related formulae where possible

For P4, evidence must include the use of sine, cosine and tangent. Several different vehicle-related problems could be posed so that each trigonometric ratio is utilised. The ability to use radians also needs to be included and this can be evidenced through a separate problem.

For P5, learners are to produce graphs showing each trigonometric function over a complete cycle. The completed graph should contain all functions and be supported by evidence of calculations, carried out either manually or via software.

P6 should be related to land-based vehicle related tasks. Learners should work on a minimum of two problems utilising the sine rule and two problems utilising the cosine rule. However, where possible, more complex problems should be posed that require the use of both rules together, ideally one problem that requires the use of each rule twice.

For P7, learners need to demonstrate the use of standard formula to calculate volumes and surface areas of three different components. Evidence may be in the form of calculations related to volumes of oil in hydraulic actuators, surface areas of diesel tanks, volume of liquids in containers that are not completely full etc.

P8 requires learners to gather statistical data to produce statistical diagrams. A minimum of 50 readings will produce enough data for the production of accurate diagrams. The presentation of the data could form part of a report.

P9 is linked to P8. The data from P8 should be analysed to find the mean, mode and median for two different statistical problems. Learners should explain the differences between each average and highlight where the difference occurs.

For P10, learners must differentiate three functions and integrate two functions. Evidence could be in the form of fully worked calculations.

M1 is linked to P3 and takes the manipulation of formula further. Learners must derive a new formula based on another that has three unknowns. This also links to M4. The problem posed for M1 could link surface

area of a cuboid tank and volume together where base x height x width become a function of each other, for example height is 2x base and width is 0.5x base.

M2 links directly to and extends P4. Evidence must include the use of inverse sine, inverse cosine and inverse tangent to solve land-based engineering related problems.

M3 links to P8 and P9. Learners must extrapolate data accurately from any graphs produced to predict future trends. They will need to fully explain their findings.

For M4, learners should use differentiation techniques to calculate the minimum surface area than can be achieved when given a shape with a fixed volume. For example, work out the minimum amount of metal required to manufacture a trailer that will hold 18 m^3.

D1 extends learners' ability to use algebra in the solution of quadratic equations. Learners should solve quadratic formula using the formula method, the factorisation method and prove their answers by plotting the graph of the equation.

D2 links to M4. Learners should prove their answer to M4 by plotting a graph that shows the minimum surface area of a shape that has a given volume. They should then suggest alternative shapes and select an alternative that has less surface area. Learners should prove their selection with calculus or another means.

Programme of suggested assignments

The following table shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1	Use of Engineering Equations	There are many equations that are used in engineering, your ability to manipulate, rearrange and work with formulae will provide a sound foundation to engineering mathematics.	Open Book Exam. Learner notes.
P4, P5, P6, P7, M2	Application of Engineering Mathematics	The knowledge of engineering mathematics can be fully utilised in many land-based engineering contexts. Use trigonometry to calculate heights of buildings, cranes, tele-handler boom heights, use standard formulae to calculate hydraulic actuator volumes etc.	Assignment. Questions relating to problems that are solved through the use of circular and triangular measurement.
P8, P9, M3	Engineering Statistics	Your ability to use software to produce charts that represent changing information is key to describing many land-based problems. Gather data that can be used to explain and then predict future trends in a chosen land-based sector.	Assignment/report. Investigative study.
P10, M4, D2	Calculus	Algebra can be used up to a point in engineering mathematics. When algebra reaches its limit, calculus can give the answers. Use calculus to solve problems that would be difficult or laborious if tackled using alternative methods.	Assignment.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC land-based sector suite. This unit links to many units in this specification and has particular links with:

Level 2	Level 3
Land-based Engineering Operations – Use Calculations	Applications of Science in Land-based Engineering

Essential resources

As a minimum, centres will need to provide learners with access to workshop facilities to enable practical investigation and data collection.

Employer engagement and vocational contexts

Learners could be introduced to a variety of professionals from different companies and organisations particularly in the research and design areas of land-based engineering, where mathematical calculations form the major part of any decision- making process. The use of calculus to quickly determine the minimum surface area of a shape with a given volume has direct implications on manufacturing and learners should be made aware of this.

Indicative reading for learners

Textbooks

Taylor G, Fuller A and Greer A – *BTEC National Mathematics for Technicians, 3rd Edition* (Nelson Thornes, 2004) ISBN 0748779493

Websites

www.calculus.org	calculus resources
www.efunda.com	online reference for engineers

Delivery of personal, learning and thinking skills (PLTS)

The following table identifies the PLTS opportunities that have been included within the assessment criteria of this unit:

Skill	When learners are ...
Independent enquirers	using and manipulating formula
Creative thinkers	writing reports, suggesting alternative shapes
Reflective learners	calculating answers to problems
Team workers	recording information
Self-managers	working on assignments
Effective participators	collecting data.

Although PLTS opportunities are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	planning and carrying out research activities related to the unit evaluating and carrying out extended thinking
Creative thinkers	asking questions to extend their thinking during lectures and practical sessions
Reflective learners	identifying opportunities for their own achievements setting goals for themselves
Team workers	working with others to carry out planning and recording
Self-managers	showing initiative and commitment dealing with pressures
Effective participators	discussing possible alternative solutions.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	producing reports based on statistical measures
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	
Manage information storage to enable efficient retrieval	
Follow and understand the need for safety and security practices	
Troubleshoot	
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	suggesting alternative solutions to problems
Identify the situation or problem and the mathematical methods needed to tackle it	
Select and apply a range of skills to find solutions	
Use appropriate checking procedures and evaluate their effectiveness at each stage	
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	
Draw conclusions and provide mathematical justifications	
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	actively participating in discussions.
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	