Unit 3: Mathematics in Construction and the Built Environment

Unit code: J/600/0451

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to enable learners to use mathematical techniques and methods to manipulate and/or solve formulae, equations and algebraic expressions. Learners will be able to select and apply mathematical, geometric, trigonometric, graphical and statistical techniques to solve practical construction problems.

Unit introduction

Construction, civil engineering and building services engineering are technical disciplines which require the collection, processing and use of numerical data. For example, in a simple construction project the dimensions of a structure are designed and specified by the architect or engineer, the cost of the work is determined by the cost control surveyor, the quantity of materials to be ordered is determined by the buyer, and the setting out dimensions and angles may be calculated by the contractor. In more complex situations, design engineers use various formulae to calculate properties such as the rate of the flow of water through pipes for drainage calculations, or the levels of bending moments in beams for sizing structural elements.

It is therefore essential that learners develop an appropriate understanding of the mathematical methods and techniques required for these key activities, and of how to apply them correctly.

The unit explores the rules for manipulating formulae and equations, calculating lengths, areas and volumes, determining trigonometric and geometric properties, and applying graphical and statistical techniques.

On completion of the unit learners will be able to select and apply appropriate mathematical techniques to address a wide variety of standard, practical, industry-related problems.

Learning outcomes

On completion of this unit a learner should:

1 Be able to use basic underpinning mathematical techniques and methods to manipulate and/or solve formulae, equations and algebraic expressions

2 Be able to select and apply mathematical techniques correctly to solve practical construction problems involving perimeters, areas and volumes

3 Be able to select and apply geometric and trigonometric techniques correctly to solve practical construction problems

4 Be able to select and apply graphical and statistical techniques correctly to solve practical construction problems.

Unit content

1 Be able to use basic underpinning mathematical techniques and methods to manipulate and/or solve formulae, equations and algebraic expressions

Calculator functions: add; subtract; multiply; divide; sin; cos; tan; arc sin; arc cos; arc tan; exponents; radians

Techniques and methods: mathematical operators; factorisation; expansion; transposition; substitution and elimination; rounding; decimal places; significant figures; approximation; truncation errors and accuracy; calculator functions and use

Formulae, equations and algebraic expressions: linear; simultaneous; quadratic equations; arithmetic progressions; binomial theorem

2 Be able to select and apply mathematical techniques correctly to solve practical construction problems involving perimeters, areas and volumes

Mathematical techniques: simple mensuration formulae and numerical integration methods (mid-ordinate rule; trapezoidal rule; Simpson's rule)

Practical construction problems involving perimeters, areas and volumes: calculations for simple and compound shapes eg rectangles, trapeziums, triangles, prisms, circles, spheres, pyramids, cones and regular and irregular surface areas and volumes

3 Be able to select and apply geometric and trigonometric techniques correctly to solve practical construction problems

Trigonometric techniques: sine, cosine, tangent ratios; sine rule; cosine rule; triangle area rules

Geometric techniques: properties of points, lines, angles, curves and planes; Pythagoras' rule; radians; arc lengths and areas of sectors

Practical construction problems: geometric techniques to determine length, area and volume for shapes containing straight lines and curves; use of trigonometry to determine dimensions in 2D and 3D eg surveying, setting out, dimensions of pitched roof and similar

4 Be able to select and apply graphical and statistical techniques correctly to solve practical construction problems

Graphical techniques: Cartesian and polar co-ordinates; intersections of graph lines with axes; gradients of straight lines and curves; equations of graphs; areas under graphs; solution of simultaneous and quadratic equations

Statistical techniques: processing large groups of data to achieve mean, median, mode and standard deviation; cumulative frequency, quartiles, quartile range; methods of visual presentation

Practical construction problems: use of graphs to solve construction problems; use of statistics to present data and make decisions based on statistical data

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 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	use the main functions of a scientific calculator to perform calculations, applying manual checks to results [IE1, IE2, IE4, IE6, RL3, RL4]	**M1**	use algebraic methods to solve linear, quadratic simultaneous linear and quadratic equations	**D1**	independently carry out checks on calculations using relevant alternative mathematical methods, making appropriate judgements on the outcome
P2	use standard mathematical techniques to simplify expressions and solve problems using linear formulae [IE1, IE2, IE4, IE6, RL3, RL4]				
P3	use graphical methods to solve linear and quadratic equations [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]				
P4	use mathematical techniques to solve construction problems associated with simple perimeters, areas and volumes [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]	**M2**	apply appropriate algebraic methods to find lengths, angles, areas and volumes for one 2D and one 3D complex construction industry-related problem	**D2**	demonstrate an understanding of the limitations of certain solutions in terms of accuracy, approximations and rounding errors
P5	use trigonometric techniques to solve simple 2D construction problems [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]				
P6	use geometric techniques to solve simple construction problems [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]				

Assessment and grading criteria					
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P7	use graphical techniques to solve practical construction problems [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]	**M3**	use standard deviation techniques to compare the quality of manufactured products used in the construction industry.		
P8	use statistical techniques to solve practical construction problems. [IE1, IE2, IE4, IE6, CT1, RL3, RL4, SM3]				

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills which are embedded in the assessment of this unit. By achieving the criteria, learners will have demonstrated 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

It is important that learners have the basic 'toolkit' for simplifying and solving a variety of formulae and expressions. Practical mathematics has at its core some fundamental techniques and methods which must become second nature to learners. To achieve this unit, learners need time to follow through worked examples under tutor guidance and then practise this work at their own pace. Work should not be seen as a rote memory exercise but as the application of basic rules as part of a structured and logical procedure. In this way learners will be able to cope with a variety of numerical problems that come their way in the course of their studies and later on during their professional career.

Learning outcome 1 forms the basis for all the following learning outcomes and should, therefore, be covered first. Learning outcomes 2 and 3 reflect the application of important mathematical skills and techniques in the solution of spatial problems using mensuration, geometry and trigonometric methods and techniques. Learning outcome 4 covers the separate topic of statistics and their presentation, analysis and interpretation. This structure would indicate the use of at least three assessment instruments.

Teaching and learning strategies designed to support delivery of this unit should involve theory, worked examples and then, most importantly, practice. Learners must be given opportunities to practise the relevant techniques. The use of formative tests and coursework will help learners to see where they may be going wrong. Within the scheme of work time should be allowed for regular workshops and/or tutorials to reinforce the learning process. It would also be beneficial to provide additional support and tutoring for less able learners through qualified classroom assistants or other forms of learning support. Delivery should stimulate, motivate, educate and enthuse learners.

It is anticipated that this unit will be delivered in the first year of the programme so an early foundation is established for the technical and numerically-based units that follow.

Group activities are permissible, but tutors will need to ensure that individual learners have equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken before practical activities are taken. Centres are advised to read the *Delivery approach* section in the specification.

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 demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction to unit
Formal delivery on methods and techniques, in stages Practical exercises Formative test
Assignment 1: Mathematical Techniques and Methods
Case studies showing practical applications of methods and techniques Visits to sites showing practical applications Formal delivery on perimeters, areas and volumes Practical exercises Formative test Formal delivery on geometry and trigonometry Practical exercises Formative test
Assignment 2: Construction Problem Solving
Formal delivery on graphical and statistical techniques Practical exercises Formative test
Assignment 3: Graphical and Statistical Problem Solving
Review of unit and assignment feedback

Assessment

Evidence for this unit may be gathered from short, time-controlled phase tests, tutor-provided practical construction scenarios, case studies, practical work or traditional example-based methods.

There are many suitable forms of assessment that could be used and some example assessment approaches are suggested below. However, these are not intended to be prescriptive or restrictive, and are provided as an illustration of the alternative forms of assessment evidence that would be acceptable.

Some criteria can be assessed directly by the tutor during practical activities. If this approach is used, suitable evidence would be observation records or witness statements. Guidance on the use of these is provided on the Pearson website.

A variety of assessment instruments should be used. For earlier work involving the basic rules of algebra it is suggested that a short, time-controlled assignment is used with some revision coaching. This will stimulate knowledge and understanding of the basic techniques and methods, as well as developing mental agility. The assessments involving applied mensuration, geometry and trigonometry could be written into practical scenario-based problems that reflect the vocational pathway being studied. The final section on statistics could be in the form of a seminar or oral presentation including the production of visual aids and the use of spreadsheets. There could also be useful opportunities for self- and peer assessment in this type of situation, but this would need to be balanced carefully against tutor assessment to ensure the validity of the evidence.

To achieve a pass grade learners must meet the eight pass criteria listed in the grading grid.

For P1, learners must be able to use the main functions of a scientific calculator with confidence and efficiency and produce rough mental and manual checks for their answers. They should give their answers in the appropriate form taking into account truncation, rounding and standard form. In all industry-related problems the correct units should be used.

For P2, learners must set out the solutions using the correct mathematical conventions. All solutions to formulae should be re-substituted back to check answers. Minor oversights are acceptable when simplifying expressions provided that the majority of the work and methods are correct.

For P3, learners should use graphical methods to solve two problems, one a linear and the second a quadratic equation problem. For simple linear solutions learners will be expected to plot graphs by appropriate selection of a range of *x*-variables. For more complex types, such as simultaneous equation or those including powers, the range of values can be provided. All graphs should be annotated and labelled correctly.

For P4, learners should provide solutions which clearly show how they have approached the mensuration problem and collated the data, for example the appropriate use of labelled diagrams. The solutions should be set out methodically and using the correct mathematical conventions clearly. Units should be clearly stated for the problems involving physical properties.

For P5, learners should provide solutions which clearly show how they have approached the trigonometric problem and collated the data, for example the appropriate use of labelled diagrams. The solutions should be set out methodically and using the correct mathematical conventions clearly. Units should be clearly stated for the problems involving physical properties.

For P6, learners should provide solutions which clearly show how they have approached the geometric problem and collated the data, for example the appropriate use of labelled diagrams. The solutions should be set out methodically and using the correct mathematical conventions clearly. Units should be clearly stated for the problems involving physical properties.

For P7, learners must use graphical techniques to solve practical construction problems. This relates to the production, interpretation and use of graphs, not to other drawing techniques such as the use of graphical solutions to solve problems associated with concurrent forces, such as those acting in frames. This is not a requirement here.

For P8, learners need to demonstrate how industry-related statistical data is calculated, presented and used to aid decision making. The calculation of values and their representation can be integrated within spreadsheet work. Learners should interpret the results and draw relevant conclusions.

To achieve a merit grade learners must meet all of the pass criteria and the three merit grade criteria.

For M1, learners, with minimal tutor support, should demonstrate how to solve linear, quadratic and simultaneous linear and quadratic equations using solution by formula, by factorisation and by the 'perfect squares' method. The structure and layout of the solutions should show a correct and methodical progression through the various stages of the calculations.

For M2, learners, with minimal tutor support, should be able to extract data from complex industry-related problems: one 2D and one 3D. They should present and apply the data to suitable mathematical models and perform the necessary calculations. The solutions should be set out methodically and using the correct mathematical conventions clearly. The units should be clearly stated throughout.

For M3, learners, with minimal tutor support, should be able to use standard deviation techniques to compare and comment on the material properties of manufactured products, for example cube test strength and steel tensile strength. Access to secondary research data will be sufficient to cover this criterion.

To achieve a distinction grade learners must meet all of the pass criteria and merit grade criteria and the two distinction grade criteria.

For D1, learners should, independently, carry out alternative mathematical methods to check solutions, using appropriate and relevant techniques A high level of clarity and presentation should be displayed. For example, this could include the learner developing and using spreadsheets independently for complex multi-stage calculations to confirm manually-generated results. Learners would also be expected to draw suitable conclusions from the resultant outcomes that relate to industrial situations.

For D2, learners should demonstrate an understanding of the limitations of certain solutions in terms of accuracy, approximations, rounding errors and the application of binomial theory to small errors. They should, independently, demonstrate an understanding of the accuracy and rounding of data, and its effect on calculated outcomes. This includes the application of binomial theory to small errors. Suitable conclusions should be made on the resultant outcomes, in an industrial context.

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 write their own assignments or adapt any Pearson assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1	Mathematical Techniques and Methods	As a training manager who supervises new apprentices to support their studies, you have been asked to prepare materials on mathematical techniques and methods for the new apprentices.	Case studies Practical work using construction scenarios.
P4, P5, P6, M2, D2	Construction Problem Solving	You have been contracted as a mathematical consultant to solve and confirm a number of mathematical problems/ solutions for projects on a major contract for the government.	Case studies Practical work using construction scenarios.
P7, P8, M3	Graphical and Statistical Problem Solving	You have been contracted as a mathematical consultant to solve and confirm a number of mathematical problems/ solutions for projects on a major contract for the government.	Case studies Practical work using construction scenarios.

Links to other BTEC units

This unit forms part of the BTEC Construction and the Built Environment sector suite. This unit has particular links with the following unit titles in the Construction and the Built Environment suite:

Level 1	Level 2	Level 3
		Unit 4: Science and Materials in Construction and the Built Environment

Essential resources

The application of mathematical techniques requires little in the way of resources other than scientific calculators and drawing equipment. Both of these are implicit requirements of many other units and, therefore, no additional resources are required for this unit other than a range of industry-contextualised, realistic and feasible project material appropriate to the application of a range of mathematical methods.

Where spreadsheets are incorporated into the delivery or assessment scheme, learners should be given appropriate access to suitable software.

Employer engagement and vocational contexts

Support to enable centres to initiate and establish links to industry, and to networks arranging visits to industry and from property practitioners is given below:

- Learning and Skills Network
- National Education and Business Partnership Network
- The Royal Institution of Chartered Surveyors

Delivery of personal, learning and thinking skills (PLTS)

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Creative thinkers	solving mathematical problems
Independent enquirers	checking the results of their calculations
Reflective learners	reviewing their progress in performing calculations
Self-managers	solving mathematical problems.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	seeking secondary data eg to find the values of constants associated with materials
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	using a spreadsheet to calculate values and present them in an appropriate fashion
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	using a calculator to perform scientific calculations
Identify the situation or problem and the mathematical methods needed to tackle it	solving construction problems
Select and apply a range of skills to find solutions	solving construction problems
Use appropriate checking procedures and evaluate their effectiveness at each stage	doing manual checks on calculations performed using a calculator
English	
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	recording data and processing it.