Unit 3: Mathematics in Construction and the Built Environment

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

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 quantities of materials to be ordered are 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 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 acceptable 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 manipulation of formulae and equations, calculation of lengths, areas and volumes, determination of trigonometric and geometric properties, and the application of graphical and statistical techniques.

Upon completion 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 Know the basic underpinning mathematical techniques and methods used to manipulate and/or solve formulae, equations and algebraic expressions

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

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

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

Unit content

1 **Know the basic underpinning mathematical techniques and methods used to manipulate and/or solve formulae, equations and algebraic expressions**

Mathematical techniques and methods: mathematical operators; factorization; 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; and quadratic equations; arithmetic progressions; binomial theorem

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

Perimeters, areas and volumes: calculations both for simple and compound shapes, eg rectangles, trapeziums, triangles, prisms, circles, spheres, pyramids, cones and both regular and irregular surface areas and volumes

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

3 **Be able to select and correctly apply a variety of geometric and trigonometric techniques to solve practical construction problems**

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

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

4 **Be able to select and correctly apply a variety of graphical and statistical techniques 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

Grading grid

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

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 and apply manual checks to results	M1 select and apply a variety of algebraic methods to solve linear, quadratic and simultaneous linear and quadratic equations	D1 independently undertake checks on calculations using relevant alternative mathematical methods and make appropriate judgments on the outcome
P2 use standard mathematical manipulation techniques to simplify expressions and solve a variety of linear formulae	M2 extract data, select and apply appropriate algebraic methods to find lengths, angles, areas and volumes for one 2D and one 3D complex construction industry related problems	D2 independently demonstrate an understanding of the limitations of certain solutions in terms of accuracy, approximations and rounding errors.
P3 use graphical methods to solve linear and quadratic equations		
P4 produce clear and accurate answers to a variety of problems associated with simple perimeters, areas and volumes	M3 use standard deviation techniques to compare the quality of manufactured products used in the construction industry.	
P5 produce clear and accurate answers to a variety of simple 2D trigonometric problems		

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:**
P6 produce clear and accurate answers to a variety of simple geometric problems P7 describe and illustrate the use of statistics in the construction industry.		

Essential guidance for tutors

Delivery

It is important that learners possess the basic tool kit 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 the learner. To achieve this the learners need time to follow through worked examples under the guidance of the tutor and then practise this work at their own pace. The 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 they 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 outcomes and should therefore be covered first. The following two learning outcomes reflect the application of important mathematical skills and techniques in the solution of spatial problems using mensuration, geometry and trigonometric methods and techniques. The final learning outcome covers the separate topic of statistics and their presentation, analysis and interpretation. This structure would therefore indicate 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. Practice is the key word and the learners must be given many opportunities to practise the relevant techniques. The use of formative tests and coursework will help the learner to see where they may be going wrong. Within the scheme of work there should be time allowed for regular workshops and/or tutorials to reinforce the learning process. It would also be beneficial to provide additional support and tutoring for the weaker learner through the provision of qualified classroom assistants or other forms of learning support. Delivery should stimulate, motivate, educate and enthuse the learner.

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

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

Health, safety and welfare issues are paramount and should be strictly reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken prior to practical activities. Centres are advised to read the *Delivery approach* section on page 24, and *Annexe G: Provision and Use of Work Equipment Regulations 1998 (PUWER)*.

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 employed. Some examples of possible 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. General guidance on the design of suitable assignments is available on page 19 of this specification.

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 Edexcel website.

A variety of assessment instruments should be used. For the earlier work involving the basic rules of algebra it is suggested that a short time-controlled assignment is given with some degree of revision coaching provided. 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 carefully balanced against tutor assessment to ensure the validity of the evidence.

To achieve a pass grade learners must meet the seven 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 be able to produce rough mental and manual checks on the answers achieved. 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, 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 correctly annotated and labelled.

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

For P7, learners need to demonstrate how industry-related data is calculated and presented. 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 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 clearly using the correct mathematical conventions. 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, eg 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 undertake 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 independently developing and using spreadsheets for complex multi-stage calculation 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 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.

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

It is anticipated that this unit will be delivered within the early stages of the programme. This will enable the learner to apply the underpinning knowledge, skills and understanding gained in this unit to the study of other, more specialised units.

This unit builds upon the knowledge, understanding and skills gained through the Mathematics taught at Key Stage 4, and underpins progression to the numerically-based units within the BTEC National Diploma, including: *Unit 4*: *Science and Materials in Construction and the Built Environme*nt; *Unit 13*: *Environmental Science in Construction*; *Unit 14*: *Structural Mechanics in Construction and Civil Engineering*, *Unit 19*: *Further Mathematics in Construction and the Built Environment,* and various building services units.

The unit has no direct mapping links to the CIC Occupational Standards at Level 3.

The unit provides opportunities to gain Level 3 key skills in: application of number; and information and communication technology. Opportunities for satisfying requirements for Wider Curriculum Mapping are summarised in *Annexe F: Wider curriculum mapping*.

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 extra 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 provided with the appropriate access to suitable software.

Indicative reading for learners

Textbooks

Bird and May — *Technician Mathematics 2, 3rd Edition* (Pearman, 1994) ISBN 0582234271

Greer and Taylor — *BTEC National NII: Mathematics for Technicians* (Nelson Thornes, 1994) ISBN 0748717013

Tourret A — *Applying Maths in Construction: Student Book* (Architectural Press, 1997) ISBN 0340652950

Tourret A and Humphreys — *Applying Maths in Construction: Teacher's Pack* (Architectural Press, 1997) ISBN 0340652969

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Staff should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• performing standard calculations associated with mensuration, trigonometry or geometry • selecting appropriate formulae to solve industry-related problems • using appropriate formulae to solve industry-related problems • interpreting, presenting and justifying the results of calculations.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use your information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae. N3.3 Interpret the results of your calculations, present your findings and justify your methods.
Information and communication technology Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• researching industry data to analyse statistical trends and means • manipulating and presenting data using spreadsheets • undertaking checks on manual calculations by developing and using relevant spreadsheets.	ICT3.1 Search for information, using different sources, and multiple search criteria in at least one case. ICT3.2 Enter and develop the information and derive new information. ICT3.3 Present combined information such as text with image, text with number, image with number.