Unit 6: Construction Mathematics

Delivery guidance

This mandatory unit for the Diploma and Extended Diploma will give learners the underlying mathematical skills and knowledge they need to solve problems related to the design, construction and refurbishment of buildings and infrastructure.

Approaching the unit

In this unit learners will develop an appropriate understanding of the mathematical methods and techniques required for key activities and how to apply them correctly. For example, in a simple construction project the dimensions of a structure are designed and specified by the architect or engineer; area and volume calculations are determined for cost purposes 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.

This unit will introduce learners to rules for manipulating formulae and equations, calculating lengths, areas and volumes, determining trigonometric and geometric properties, and applying graphical and statistical techniques. There are opportunities for you to deliver this unit in a specialist context such as construction and the built environment, building services or civil engineering. However, care must be taken to ensure learners are prepared for the Pearson set assignment and that the full breadth of the unit content is covered.

Delivery of the unit is likely to use a range of methods, including a large proportion of tutor presentations and demonstrations, along with individual, paired and group work when carrying out data collection activities, practice calculations and problem-solving activities. On completion of the unit, learners will be able to select and apply appropriate mathematical techniques to address a wide variety of standard, practical and industry-related problems. The unit will also enable learners to access more advanced mathematical based units on their respective learning pathway.

You could involve local employers in the delivery of this unit if there are opportunities to do so – for example, through site visits to apply concepts associated with mensuration or for the collection of data to analyse.

Delivering the learning aims

Learning aim A will introduce learners to the principles and techniques required to solve construction-related problems, including the use of calculator functions, mathematical and algebraic techniques. The main focus of the learning aim is to give learners the underpinning skills they will need when working through calculations and analysis for the other three learning aims in this unit.

Learning aim B will investigate the use of mensuration techniques that can be used to solve construction problems involving perimeters, areas and volumes. Learners need to understand the basic techniques of mensuration, including the use of formulae before moving on to develop skills needed to carry out calculations involving both simple and compound shapes for regular and irregular shapes, surface areas and volumes.

Learners would benefit from opportunities to apply the skills they have developed to a range of construction problems – for example, calculating areas of development sites or volumes of materials that need to be excavated. Learners should then be introduced to circular measure, with examples of the use of radian measure in construction situations.

You could then move on to learning aim C by introducing learners to the underpinning principles of trigonometry (including trigonometric ratios) and more advanced trigonometry (including the sine and cosine rules). You could develop this further by introducing geometric techniques related to construction problems before reviewing the use of radians for circular measurement. You give learners an opportunity to develop the basic skills required to solve construction problems set within appropriate scenarios. Learners could then be given a range of activities that build in complexity in order to practise these skills and become familiar with the techniques they will need to apply.

Where possible, learners should be given the opportunity to collect and analyse data for learning aim D. This will allow them to carry out statistical analysis, which could be linked with other construction-related problems such as a traffic census, occupancy rates, sound levels or temperatures. Concepts such as producing graphical solutions to problems involving graphs, simultaneous equations and quadratic problems should then be introduced to learners, again with an emphasis on real-life construction concepts.

Assessment model

Learning aim	Key content areas	Assessment approach
A Understand basic underpinning mathematical techniques and methods to manipulate and/or solve formulae, equations and algebraic expressions	**A1** Calculator functions **A2** Mathematical techniques including issues or rounding/accuracy **A3** Algebraic techniques and expressions	• A report containing calculations and interpretation of results for a variety of standard, practical and industry constructed related problems.
B Examine and apply mathematical techniques correctly to solve practical construction problems involving perimeters, areas and volumes	**B1** Mensuration techniques **B2** Solving of practical construction problems involving perimeters, areas and volumes **B3** Circular measures	
C Examine and apply geometric and trigonometric techniques correctly to solve practical construction problems	**C1** Trigonometric techniques **C2** Geometric techniques **C3** Solving of practical construction problems	A report containing calculations and interpretation of results for a variety of standard, practical and industry constructed related problems.
D Investigate the use of statistical and graphical methods correctly to solve construction problems	**D1** Statistical techniques **D2** Graphical techniques **D3** Solving of practical construction problems	• A report that includes appropriate graphs, charts and analysis of statistical data for a series of construction related problems.

Note Learning aims A and B are assessed in one assignment, as are learning aims C and D, which are also assessed in one assignment.

Assessment guidance

This unit is assessed with a maximum of two assignments being permitted. Assignment 1 should cover learning aims A and B, and Assignment 2 should cover learning aims C and D. The assignment briefs should be set within the context of construction and built environment, with opportunities to set tasks linked to specific pathways.

For Assignment 1, tasks should give learners the opportunity to complete a wide range of construction problems by applying mathematical and algebraic skills. Care should be taken to make sure learners are able to check calculations using alternative methods and approaches.

For Assignment 2, tasks should be written to allow learners to demonstrate their ability to manipulate and analyse data to draw conclusions and to use suitable geometric and trigonometric techniques to solve 2D and 3D construction problems.

Submitted assessment evidence could be in the form of calculations, diagrams, drawings and charts.

Getting started

This give you a starting place for one way of delivering the unit, based around the recommended assessment approach in the specification.

Unit 6: Construction Mathematics
Introduction
In the delivery of this unit, there are opportunities for you to develop links with a range of local organisations including construction companies, materials suppliers and, to an extent, landowners and local authorities. These organisations may be able to give information about construction sites or designs of buildings and developments that can be used as starting points for scenarios to use when delivering new topics.
Centres may consider it appropriate to deliver aspects of learning aim A1 throughout the teaching of the other topics, as and when opportunities arise, as the use of these functions would be better taught in context. Similarly, learning aim A2 could be revisited throughout the teaching of the other learning aims to reinforce understanding.
Where possible you should apply the learning to appropriate construction contexts, especially when considering concepts such as approximation, accuracy and the use of formulae.

Learning aim A – Understand basic underpinning mathematical techniques and methods to manipulate and/or solve formulae, equations and algebraic expressions
Learning aim A1
● You could introduce this learning aim by asking learners to assess their understanding of mathematical and algebraic techniques they may have used in their previous studies. You could ask learners to assist with the completion of example calculations and offer support and guidance where necessary.
● This could be followed by learners being guided in the methods they need to follow when using a calculator to solve construction mathematics problems.
● Learners could be divided into small groups and given a range of worksheets to complete using calculators to allow them to become familiar with the range of functions available and how to present answers using standard form.
● You could then review the tasks completed by groups and offer support and guidance where mistakes have been made, giving model answers for questions where common errors were seen.
Learning aim A2
● Moving on, you could introduce learners to the range of mathematical techniques in learning aim A2. Begin by reviewing the mathematical operators that have been used with calculators for learning aim A1.
● Once learners are secure in their understanding of these, you could introduce them to techniques for manipulating equations, including factorisation and expansion. This could be supported by giving learners a range of worksheets to complete.

Unit 6: Construction Mathematics

- When learners are confident with their ability to manipulate formulae, you could demonstrate how to transpose formulae and then substitute and eliminate values to reach solutions. As with other concepts, learners should be given an opportunity to practise techniques through the use of differentiated worksheets.

- You could then introduce learners to the use of decimal places and significant figures for presenting values. Care will be needed to make sure learners are clear in the difference between the two. This could be supported through the use of worksheets where learners need to present values to given numbers of decimal places and/or significant figures.

- The concept of significant figures could naturally lead on to introducing the use of approximation to check calculations. You could demonstrate to learners how the use of rounded values can be used in calculations to give an approximate answer to a calculation.

- This could be followed with an explanation of the consequences of truncating values on the accuracy of a solution. You could demonstrate this through the use of truncated values to calculate the area of a surface and the impact this may have on the accuracy of an order for materials.

- Finally, you could demonstrate to learners the approaches needed for more complex formulae including those with exponents, roots and trigonometric identities. Again, learners could be given worksheets with questions of increasing difficulty to check their understanding.

Learning aim A3

- This could be introduced by discussing learners' prior experience of using algebraic methods to solve problems including skills in manipulating formulae.

- You could then demonstrate linear equations to learners, using graphical techniques to explain equations of straight lines. Learners could then complete tasks to both draw straight-line graphs from formulae and also derive the equations of lines from graphs.

- Once learners have an understanding of linear equations you could then introduce simultaneous equations. This could be either through presentations or through simple assessments.

- You can then demonstrate to learners the necessary skills to rearrange quadratic formulae, and the methods of substituting values into formulae to arrive at a solution.

- You could develop learners' ability to apply algebraic concepts by introducing them to factorisation of linear and quadratic equations for which learners should be taught how to find roots of an equation by factorisation, completing the square and also using the quadratic formula.

- Learners could be given worksheets with a range of quadratic equations to solve, and they should find the roots of these equations by using appropriate techniques.

- You could then introduce the binomial theorem to learners and demonstrate to them how it can be applied to small errors.

Unit 6: Construction Mathematics

Learning aim B – Examine and apply mathematical techniques correctly to solve practical construction problems involving perimeters, areas and volumes

Learning aim B1

- You could introduce learning aim B by reviewing learners' understanding of methods that are used to calculate areas and volumes of regular shapes, asking them to recall any standard formulae they may have used previously.

- This could be followed by introducing learning aim B1 by demonstrating to learners the formulae that are used for mensuration and how these can be applied to contextualised construction problems.

- Learners could work in pairs or small groups to complete worksheets to answer questions where they would need to apply these formulae. You should offer support and guidance to learners as necessary.

- Demonstrations and worked examples could be used to introduce the numerical integration methods in learning aim B1.

- First, you could introduce the mid-ordinate rule, demonstrating to learners the process involved and how it is used to calculate the area under a curve.

- Learners could then practise the use of the mid-ordinate rule to calculate areas under curves linked to construction situations.

- Once learners are able to apply the mid-ordinate rule with accuracy you could introduce both the trapezoidal rule and Simpson's rule.

- You could set learners an activity to compare the results obtained using the three different methods for the same construction problem.

Learning aim B2

- You could introduce learning aim B2 with demonstrations to revise methods of calculating areas of regular 2D shapes. Learners could complete worksheets to practise calculation of areas.

- Once learners are competent in the calculation of areas of regular 2D shapes, you could review methods of determining surface areas of regular 3D solids and related volumes.

- You could then give learners the opportunity to work individually on solving problems related to areas and volumes.

- Once learners are confident with the calculations of areas and volumes of simple regular shapes you could move on to introduce the idea of compound shapes. These could include cylinders with hemispherical domes on top or cuboids with chamfered edges.

- You could demonstrate approaches learners can use to solve problems involving compound and irregular shapes and solids before setting them worksheet activities to practise these techniques.

Learning aim B3

- You could introduce learning aim B3 by explaining the importance of circular measurements to learners, introducing radians as the unit of circular measurement.

Unit 6: Construction Mathematics

- You could lead a demonstration to show learners how to convert from degree measurement to radians and vice versa, with learners practising these conversions in small groups.
- You could then demonstrate the advantages of using radians – especially with regard to finding arc lengths and areas of sectors.

Learning aim C – Examine and apply geometric and trigonometric techniques correctly to solve practical construction problems

Learning aim C1

- You could introduce learning aim C by explaining the use of geometry and trigonometry to solve both 2D and 3D construction problems by making reference to detail drawings or site plans and identifying where values have been omitted.
- You could then discuss with learners the range of trigonometric methods that are used for calculating lengths and angles of right-angled triangles. You could assess prior learning and understanding through the use of questioning and worked examples.
- This could be followed by whole class activities using case studies of situations where angles and lengths might need to be calculated in construction contexts. You could use images and video resources to demonstrate examples to learners of calculations being completed.
- With an understanding of the principles of trigonometry for right-angled triangles you could then move on to introduce learners first to the sine rule and then the cosine rule.
- A further activity could be to apply the sine and cosine rules to solve problems involving unknown angles and lengths – for example, between members in a structural frame.
- You could follow this by introducing learners to the triangle area rule, which can be used to calculate the area of non-right-angled triangles.
- Learners could be given a range of problems to solve that involve the combined use of trigonometry and the area rule to find solutions.

Learning aim C2

- You could introduce learning aim C2 by discussing with learners the properties of points, lines, angles, curves and planes. You could give learners an independent study activity to consider the differences and to produce brief descriptions of each.
- This could then introduce Pythagoras' theorem to learners. You could demonstrate worked examples and give learners worksheets to complete calculations.
- Moving on, you could revisit circular measure and the use of radians to calculate the areas and arc lengths of sectors of circles.

Learning aim C3

- You could introduce learning aim C3 to learners by initially demonstrating how to apply trigonometric and geometric theory to construction problems, perhaps making use of

Unit 6: Construction Mathematics

local organisations. Examples could include problems related to irregular shaped sites, building plans and elements such as structural steelwork and timbers.

- There is also an opportunity to make use of site plans and design drawings provided by local employers or government agencies to give learners the opportunity to apply the range of trigonometric functions to solve realistic 2D and 3D construction problems, such as determining the area of a site where it is not possible to make direct measurements.

Learning aim D – Investigate the use of statistical and graphical methods correctly to solve construction problems

Learning aim D1

- Learning aim D could be introduced through a discussion of how statistical information is used within the construction industry. You could ask learners for examples of situations where they think data may need to be analysed and use these as starting points for class activities.
- You could then move on to learning aim D1 and explain the differences between types of data. This could become part of an activity where learners are given data sets and need to state which category each set of data comes under.
- You could develop this further by introducing learners to methods of calculating the mean, median and mode of sets of data. This could be supported by learners working through examples independently.
- Moving on you could demonstrate how to calculate the standard deviation of sets of data with worked examples. Learners could then calculate the standard deviation of data they have been working with previously.
- With learners having an understanding of averages and standard deviation you could now move on to introduce them to the concepts of cumulative frequency, quartiles and quartile ranges.
- You could give learners paired activities to determine the cumulative frequency, quartile and inter-quartile ranges of the data they have previously analysed.
- You could lead a class discussion to review the use of visual presentation methods used for statistical data. You could discuss with learners the types of methods that can be used and where each is appropriate.
- You could then give learners either practical data collection exercises or desk studies to develop their skills in the interpretation, application and presentation of statistical information.
- These should give learners sufficient opportunity to gain an understanding of a wide range of types of data, and the methods used to present them. You could give contextualised problems related to local construction projects – for example, results of concrete cube tests or a traffic survey.

Learning aim D2

- You could introduce learning aim D2 by discussing with learners the difference between polar and Cartesian coordinates.

Unit 6: Construction Mathematics

- This could be followed by demonstrating methods of interpreting and plotting graphs of linear equations before giving learners a range of equations they should plot for themselves. A similar approach could be taken for curves.
- You could develop the concept of straight-line graphs by demonstrating how the area under a straight-line graph is calculated before giving learners a range of questions to work through.
- Once learners are confident with the production and interpretation of straight-line graphs, you could demonstrate how to use a graphical method to solve pairs of simultaneous equations. Learners could then practise using worksheets.
- You could introduce the use of graphical methods to find the roots of quadratic equations through the use of worked examples or video resources. Learners could plot quadratic functions to find the roots using either a spreadsheet or graph paper.

Learning aim D3

- You could draw together the various statistical techniques and graphical techniques in learning aim D3 by demonstrating to learners how graphs and statistics are used to solve construction problems.
- Learners could then be given a range of problems linked to locally based scenarios that will allow them to demonstrate their ability to interpret and present statistics and also apply graphical techniques.

Details of links to other BTEC units and qualifications, and to other relevant units/qualifications

This unit links to:

- Unit 10: Surveying in Construction
- Unit 12: Building Surveying in Construction
- Unit 13: Site Engineering for Construction
- Unit 15: Measurement Techniques in Construction
- Unit 17: Further Mathematics in Construction
- Unit 20: Quantity Surveying
- Unit 23: Construction in Civil Engineering

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC Internationals in Construction. Check the Pearson website (http://qualifications.pearson.com/endorsed-resources) for more information as titles achieve endorsement.

Textbooks

Tourret A, Humphreys J, *Applying Maths in Construction*, Routledge, 2013 ISBN 9781136069727 – examples of applications of a range of mathematical approaches to construction contexts

Virdi S, Baker R and Kaur Virdi N, *Construction Mathematics*, Routledge, 2014 ISBN 9781135055226 – includes theory and examples of a range of topics including algebra, trigonometry, statistics and geometry

Wilkinson C, *Using Math in Construction*, Rosen Publishing Group, 2017 ISBN 9781499438550 – includes scenarios and applications of arithmetic, algebra, geometry and trigonometry in construction contexts

YouTube videos

'Factorising algebraic expressions' – worked examples of factorisation of quadratic equations

'Mode, median, mean, range and standard deviation (1.3)' – these are all covered within this video resource with worked examples

'Standard deviation – statistics' – a worked example of how to calculate the standard deviation of a set of data

'Trigonometry: solving right triangles … How? (NancyPi)' – worked examples of how to select trigonometric functions and calculate missing values for right angled triangles

'What are radians?' – introduction to radian measure and conversions between radians and degrees

Websites

mathmeeting (from Math Meeting) – a website that contains a range of video resources that cover trigonometry, statistics and algebra

mathsisfun (from Maths is Fun) – a useful web resource with links to major topics in the unit including measurement (mensuration), algebra and geometry

skillsyouneed (from Skills You Need) – search 'Numeracy skills'; this online resource covers geometry, trigonometry and statistics amongst other topics that might benefit learners who need more support in the basics of mathematics

Pearson is not responsible for the content of any external internet sites. It is essential for tutors to preview each website before using it in class so as to ensure that the URL is still accurate, relevant and appropriate. We suggest that tutors bookmark useful websites and consider enabling students to access them through the school/college intranet.