Unit 5: Mathematics for Engineering Technicians

Delivery guidance

Approaching the unit

The focus of this unit is to develop learners' understanding of the role of mathematics in engineering. Learning activities should be designed to allow learners to understand how the various mathematical skills are applied to real life engineering problems. There could be scope for you to link learning with that completed in other units, for example Ohm's Law, and the algebraic skills that need to be demonstrated when rearranging and solving equations.

It would be best to deliver the unit in the order of the two learning outcomes, although you might need to mix and match some of the content to fit in with other units that might be delivered at the same time.

Learners would benefit from being able to see the application of mathematics through practical examples and demonstrations, for example setting them applied engineering challenges which require them to use mathematical skills to reach a solution. It is likely that much of the teaching and learning will be based around demonstration of methods, worked examples and learners practising calculations, however all activities should be linked to engineering applications and have a purpose.

To deliver this unit you will need to have available scientific calculators, graph paper and mathematical instruments. Learners should be encouraged to make full use of an electronic scientific calculator and be familiar with the basic functions eg add, subtract, multiply and divide whole numbers and decimal fractions. At the appropriate stage learners should be able to use the special function keys in order to determine sine, cosine, tangent ratios, powers and roots.

For learning aim B where learners need to calculate surface areas and volumes it would benefit learners if there were physical models to look at and examine so that they can better visualise details of the solid and hollow shapes.

Delivering the Learning aims

Learning aim A focuses on the development of arithmetic and algebraic skills before moving on to graphical methods. Learners will need to build on their existing mathematical knowledge and understanding and be able to apply this knowledge to engineering problems.

Throughout learning aim A learners should be provided with opportunities to build up their confidence when problem-solving. It will also help them if tasks allow them to become proficient in the use of a scientific calculator. Whilst it is useful to be able to do mental arithmetic to check the reasonableness of solutions, at Level 2 it is more important to explore and develop an understanding of methods and techniques, the calculator can be used to do the 'number-crunching' to find solutions. It is important that any problems and practice assessments are written in a relevant engineering context, examples of which are included in this delivery guide, and are not simply mathematical questions..

Learning aim B introduces your learners into the interesting and important world of mensuration and trigonometry. These are topics that engineers of all types put to very good use. Where possible get your learners to extract data from simple engineering drawings when asking them to calculate, for example, the volume of a turned or cast component. Alternatively you could give

them examples of solid and hollow components, ask them to take its dimensions and calculate the volume.

It is important that your learners use the correct layout and mathematical conventions when presenting their work. Learners should always be encouraged to show all of their workings for calculations as the aim is to present work which can be easily read and understood by a third party. Being able to see how your learners arrived at a solution is crucial because if they misread numerical data when starting out on a solution you can still assess if they understand the analytical principles involved even if the final numerical value may be incorrect. Applying mathematical principles to find the solution to problems should not be seen as a memory test and it is perfectly acceptable for your learners to be given access to a formulae sheet, perhaps the one that is used for the Pearson Set Assignments so that they are familiar with its format and contents.

Assessment model

Learning aim	Key content areas	Recommended assessment approach
A Examine how arithmetic, algebraic and graphical methods are used to solve engineering problems	**A1** Arithmetic Methods **A2** Algebraic Methods **A3** Graphical Methods	This unit is assessed through a Pearson Set Assignment.
B Examine how Assignment. mensuration and trigonometry are used to solve engineering problems	**B1** Areas and volumes of regular and compound shapes and three dimensional objects **B2** Trigonometry	

Assessment guidance

The unit is assessed by a Pearson Set Assignment (PSA). The assessment is set by Pearson and must be taken under controlled conditions before it is marked by tutors.

There are 30 guided learning hours assigned to the unit, of which one hour will be required for assessment.

Set assignments are available from September each year and are valid for one year only.

Delivery must cover all the unit content and prepare learners to produce evidence to meet the assessment criteria and assessment guidance in preparation for taking the PSA. Sample Assessment Materials are available on the Pearson website. These can be used or adapted to help learners prepare for assessment.

Getting started

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

Introduction

Introduce this unit by discussing with learners the importance of mathematics for engineers. Ask them to suggest situations and contexts in engineering where maths is not an important aspect and then use any ideas as a starting point to discuss the fact that the application of mathematics is found throughout all of engineering, from dimensions in designs through to the length of time it takes a battery to recharge. You could show learners suitable online videos to introduce them to the aspects of engineering where it is less obvious mathematics is involved.

Learning aim A – Examine how arithmetic, algebraic and graphical methods are used to solve engineering problems

- Learning aim A is designed to provide learners with the mathematical skills that will allow them to solve a range of engineering problems that require calculations.
- For A1 you could review existing understanding of mathematical operations through the use of applied questions. This could be followed by whole-group teaching to review and develop understanding of basic arithmetic methods and working with a scientific calculator. This could include demonstrations using online scientific calculators.

  Once learners are confident with arithmetic operations you could introduce them to the principles of arithmetic precedence by demonstrating and explaining the BIDMAS rule.

  You could then introduce the concept of working with powers and roots of numbers includes squares and cubes. You could also include ways of expressing large and small numbers using powers of 10, for example, 5.35×10^{-3} or 3.14×10^{8}. This could be followed by giving learners individual activities to work out simple engineering calculations (using a calculator) and write out solutions in full to an agreed standard.

  You should explain to learners the importance of correct and logical presentation when writing out their solutions, for example by following a logical sequence of mathematical operations and showing all of their working in a way that is readable and easy to interpret.

  You could follow this by demonstrating to learners how to perform simple checks, such as approximation, to check if numerical answers are correct. This could be followed by explaining methods for approximating answers and expressing numbers of significant figures/decimal places, giving learners examples which they need to present to a given number of significant figures or decimal places.

  This could then be followed by demonstrating to learners how symbols are used, including those for values that are greater, less than, equal and not equal.

  Learners could then be shown how to work with fractions, including the range of arithmetic operations such as addition and multiplication. You could use examples such as resistors in parallel for the addition of fractions to provide an engineering context.

  Finally for A1 you could introduce learners to the use of ratios and percentages in engineering, and how these are calculated. You should use appropriate engineering contexts, such as scales for engineering drawings as an application of ratios and tolerances of resistors for percentage calculations.

- For A2 you could then introduce the concept of algebra and the use of symbols and letters to represent numerical values. You could do this through the use of whole class teaching by demonstrating to learners how to work with engineering formulae and to produce accurate numerical answers.

  You should demonstrate to learners how to rearrange formulae and equations to change the subject – Ohm's Law could be a suitable example to use, showing learners how to rearrange the equation to make V, I and R the subject in turn. You could then demonstrate how to substitute values into the equations to find solutions.

  It would help learners if you made links with other units, such as those where electrical and mechanical principles are taught, by using the formulae which feature in these other units. You could then set learners a series of questions linked to engineering concepts for them to practice transposing and solving linear engineering equations.

  When learners have gained confidence in manipulating and solving simple engineering equations you could then demonstrate to them how to transpose and solve complex engineering equations such as those listed in the unit content.

  You could then reinforce the importance of setting out calculations clearly, explaining how to set out complex calculations and ways to work with a calculator so that accuracy is maintained. You could explain to learners that showing all of their working, with steps shown clearly, allows any carry-through errors to be identified, and that it is not good practice to complete a calculation in full on a calculator with no working shown at all.

  Once learners are familiar with the processes and concepts involved, you could then give learners individual or small-group activities to solve problems set in engineering contexts, for example problems involving linear motion or charge and capacitance.

  Finally, demonstrate to learners how to carry out chained calculations using a calculator – this could again be done through the use of an online scientific calculator. Review the importance of BIDMAS covered in A1 and how the stages of calculations need to be completed in the correct order.

  linked to mathematical operations, including both positive and negative numbers as well as decimals. When completing these calculations the concepts of reasonableness for answers and rounding could be introduced. Again this should be in an engineering context, for example the number of decimal places required when calculating the acceleration of a car over 20 seconds is likely to be greater than required for the distance travelled by that same car in 2 hours.
- For A3 you could demonstrate to learners methods of producing straight line graphs from sets of experimental data. Explain why engineers present data in graphical form, demonstrate how to plot a linear relationship and extract/interpret information from it.

  There is opportunity to carry out some data collection from simple investigations such as the relationship between loading and extension for a spring. Learners will need to understand how to interpret graphs, and could be given examples for a range of investigations to then interpret the gradient, intercepts and equation of the line. The use of practical examples will benefit learners and allow them to understand the application of skills to engineering problems.

  You could then provide learners with sets of data for investigations that have a linear relationship, for example resistance in a circuit, and ask them to plot the graphs and use this to determine the equation of the line. They should have opportunity to identify coordinates in all four quadrants for graphs, therefore both positive and negative relationships will need to be included.

When learners are able to plot and interpret linear graphs you should then move on to consider non-linear and curved relationships. Again learners should be able to both plot and interpret the graphs and identify key values such as intercepts.

Learning aim B: Examine how mensuration and trigonometry are used to solve engineering problems

- Learning aim B is intended to introduce learners to methods of calculating areas, volumes and angles for different shapes. It will be important that learners understand the methods that need to be followed to calculate area and volume for both regular and compound 3D shapes. They will also need to be able to use a calculator correctly to find unknown angles and dimensions of triangles through the use of trigonometry.
- For B1, you could begin by demonstrating how to calculate the areas of simple regular shapes using given formulae. This could be followed by learners sketching shapes and writing down formulae before calculating the area of the shapes.

  You could then develop this further by explaining how compound shapes, such as the cross-section of an I-beam, can be broken down into simple regular shapes and their areas calculated. You could lead learners through a number of examples before giving learners drawings of compound shapes for them to calculate the area.

  Before moving on to volumes of shapes you could introduce learners to additive and subtractive methods when working with compound shapes, for example, subtracting the area of holes from a rectangular plate. You could then provide learners with a number of examples of engineering components such as joining plates where a number of different additions and subtractions might be needed to calculate the area.

  This could then be followed by further whole-group teaching to demonstrate how to calculate the volumes of simple regular solid and hollow objects using given formulae. At this point it would be worth sharing with learners the formulae that they will be provided with for the Pearson Set Assignment.

  Learners could then sketch out, annotate and calculate the volumes of a range of simple solid and hollow objects. This could be done through the use of physical models that learners can measure.

  Moving on, you could then explain how compound objects can be broken down into simple regular objects and their volumes calculated. You could demonstrate to learners examples of manufactured objects, such as a cylinder with conical end or angle plates and discuss with them the approaches that could be taken to calculate their areas.

  Learners could then carry out individual activities to extract dimensional data from drawings or examples of compound objects and calculate their volumes.
- For B2, you could begin by discussing with learners the characteristics of triangles and how engineers can use trigonometry to calculate angles and lengths of sides. You could then use some whole-class teaching to explain the use of Pythagoras' theorem to determine the side lengths of right-angled triangles.

  Learners could then be set a number of questions that involve the use of Pythagoras' theorem to find missing lengths from a range of right angled triangles.

  You could then move on to explain the use of the trigonometric relationships as applied to right-angled triangles. You could demonstrate to learners how to use their calculator to determine angles through the use of the 'tan', 'cos' and 'sin' buttons, showing learners how to calculate angles and the lengths of sides.

Learners could then sketch out, annotate and calculate the side lengths and internal angles of right-angled triangles.

You could then follow this up with further whole-group teaching to demonstrate how a non-right-angled triangle can be split into right-angled triangles and missing dimensions and angles calculated. Learners could then carry out individual activities in which they sketch out, annotate and calculate the side lengths and internal angles of non-right angled triangles.

You could discuss with learners applications of trigonometry in engineering, for example when calculating a resultant force for two forces at right angles, or when completing calculations for structures.

This would then naturally lead on to a demonstration of how trigonometry can be used to calculate the dimensions and angles of two-dimensional shapes made up from triangles, rectangles and squares.

Learners then carry out individual or small-group activities to sketch out, annotate and calculate the side lengths and internal angles of engineering structures that are made up from rectangles and triangles.

You could then provide learners with some practice questions that cover all of learning aim B in preparation for the completion of the Pearson Set Assignment.

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

The section for Unit 10 of the BTEC First in Engineering is useful for teaching and interpreting Unit 5.

This unit links to:

- Unit 2: Engineering Thinking Skills to Create Solutions
- Unit 7: Engineering Drawing
- Unit 8: Machining Techniques
- Unit 9: Engineering Design
- Unit 15: Engineering Marking Out
- Unit 17: 3D Printing
- Unit 19: Data Capture and Interpretation
- Unit 20: Electrical and Mechanical Science for Engineering
- Unit 21: Electronic Circuit Design and Construction
- Unit 25: Computer Numerical Control Programming
- Unit 32: Vehicle Engines and Associated Systems
- Unit 33: Vehicle Electrical/Electronic Systems
- Unit 34: Vehicle charging and battery technology

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International L2 Qualifications in Engineering. Check the Pearson website at: (http://qualifications.pearson.com/endorsed-resources) for more information as titles achieve endorsement.

Textbooks

Bird, J., *Bird's Basic Engineering Mathematics (8th edition) (Routledge 2021)* ISBN 9780367643706

Bird, J., *Bird's Engineering Mathematics (9th edition) (Routledge 2021)* ISBN 9780367643782

Content is aimed at students taking Level 2 courses

Boyce, A., Clarke, S., Darbyshire, A., Goulden, S., Hallgarth, C. and Watkins, N., *BTEC First Engineering Student Book (Full edition) (Pearson Education, 2013)* ISBN 9781446902431

Websites

web2.0calc.com/ - online scientific calculator

mathsmadeeasy.co.uk – lots of online tutorials and practice questions that cover the contents of the unit.

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.