Unit 1: Mechanical Principles

Delivery guidance

When considering the engineering industry’s future need and demand for ‘multi-skilled’ engineers, this unit aims to give the next generation of engineers the skills and capability to apply their mathematical and physical scientific knowledge.

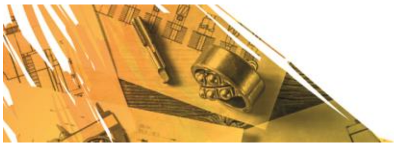
Approaching the unit

You will help learners to explore and apply algebraic and trigonometric mathematical methods to solve engineering problems.

You can use the following activities with learners in order to equip them with the necessary skill set to be successful when completing the Pearson Set Assignment Brief:

- group and whole-class discussion
- paired activities to share knowledge and skills between peers
- individual activities and research tasks to complete and document learning aims and outcomes
- tutor-led demonstrations.

This unit sits at the heart of the qualification and gives learners a foundation to support them in any engineering technician role, trainee role with an employer, or to support learners' progression into higher education.



Assessment model

Learning aim	Key content areas	Assessment approach
A Examine how algebraic and trigonometric mathematical methods can be used to solve engineering problems	**A1** Algebraic methods **A2** Trigonometric methods	This unit will be assessed through a Pearson Set Assignment. Learners will be required to interpret and use data and information relating to engineering scenarios. Learners' work will be submitted in the form of a completed assignment, which will be assessed by centre staff using the assessment criteria in this unit.
B Examine how static engineering systems can be used to solve engineering problems	**B1** Static engineering systems **B2** Loaded components	
C Examine how dynamic engineering systems can be used to solve engineering problems	**C1** Kinetic parameters **C2** Dynamic parameters **C3** Angular parameters **C4** Lifting machines	
D Examine how fluid engineering systems can be used to solve engineering problems	**D1** Fluid systems **D2** Immersed bodies	

Assessment guidance

Unit 1 is assessed via a Pearson Set Assignment. Learners will be required to interpret and use data and information relating to engineering scenarios. Learners' work will be submitted in the form of a completed assignment, which will be assessed by centre staff using the assessment criteria in this unit. This assessment will give opportunities for learners to demonstrate knowledge and understanding of the unit content on a range of engineering contexts. The assessment will contain challenges for learners of all abilities through focused and synoptic problems that will require individual and combined application of mathematical techniques and physical scientific knowledge.

Delivering the learning aims

This mandatory unit is intended to give learners the mathematical skills and knowledge of the physical principles that underpin mechanical engineering. The delivery of the unit provides an opportunity for a range of problem-solving activities, along with some practical experimentation, to gain deeper understanding of the principles involved.

Like other mandatory units, you could deliver this unit in a specialist context such as aeronautical, manufacturing or electrical and electronic engineering. For example, if you wanted to deliver mandatory units in an electrical/electronic context, you could explore a range of basic electrical products such as a kettle, or a food processor, to explore the design and manufacturing processes employed by the designers and engineers. However, take care to ensure that learners are prepared for the assignment brief that is set by Pearson.

Delivery of this unit is likely to use a range of different teaching methods, including a large proportion of tutor-led presentations, paired with individual, peer to peer and group work. Provide learners with opportunities to put theory into practice where investigating mechanical principles in order to solve engineering problems. If your centre has links with local employers, this would support the delivery of this unit.

Learners will develop the skills needed to be able to identify and respond to engineering problems so that they can employ appropriate procedures in order to arrive at justifiable responses. They should be equipped with the theoretical knowledge that will allow them to explain how systems perform, and be able to draw together knowledge from different strands of engineering to solve synoptic problems.

Learning aim A: Examine how algebraic and trigonometric mathematical methods can be used to solve engineering problems

Learning aim A provides the mathematical foundation for the unit, introducing learners to algebraic methods and then to trigonometric methods. In both cases these should be related to engineering problems and scenarios.

Review learners' understanding of linear equations and straight-line graphs and methods to solve simultaneous equations. Typical examples that could be used are with distance/time graphs, speed/time graphs and load/extension graphs. Building on this, allow learners to consider quadratic equations and methods to solve them using quadratic formulae. They should then continue to demonstrate their knowledge and understanding of algebraic methods in order to carry out conversions between angular and circular measurements.

Give learners the opportunity to apply their knowledge using formulae to solve surface areas and work out volumes of regular solids. Enable learners to demonstrate their knowledge using problems which are linked to engineering products or scenarios. Moving on, give learners the opportunity to reflect on prior learning with a recap of factorisation and quadratics, using routine methods such as roots of an equation including quadratic equations. They should be given opportunities to multiply expressions in brackets using symbols, numbers or by other expressions.

Present learners with problems which will require them to creatively solve a range of different problems. Routine and non-routine methods of mensuration will teach them the skills of translation, strategy and metacognition, valuable as their knowledge and understanding within the field of engineering develops. Through the facilitation of this you can tailor learners' lessons and personalise instructions to help them improve mathematical thinking and problem-solving performances.

Provide learners with problems in which they will use routine and non-routine trigonometric methods to perform circular and triangular measurements and conversions. The design of different structures, large or small, requires accurate understanding of length and dimensions, even when they cannot be measured. Allow learners to use trigonometric methods and relationships to find approximations to lengths and dimensions. For example, in the design of structures, engineers must ensure that forces acting on structure will balance so that they remain stationary. Trigonometric valuations and activities will allow learners to account for vertical and horizontal components of the different forces that act on structures, therefore determining that the structure will be able to stand before it has been constructed.

Learning aim B: Examine how static engineering systems can be used to solve engineering problems

Having given learners a foundation of mathematical skills and techniques that they will need to apply to a range of engineering problems, you will now introduce them to static engineering systems as an introduction to learning aim B. This will initially build directly on the work undertaken in learning aim A, with learners developing the skills needed to represent forces using free body and space diagrams. Further development of the theories relating to static equilibrium could be demonstrated visually for learners, along with the principles of movement. This should give learners the skills they need in order to investigate simple supported beams and to solve related problems.

Once learners have an understanding of forces within static systems, you should then provide more complex concepts that relate to loaded components. Initially this could be done through an investigation into direct stresses and strains using demonstrations and the provision of activities for learners to carry out calculations as appropriate. This should then lead into considering shear stress and strain, followed by shear strength and tensile strength. These concepts could be demonstrated visually to learners. Finally, you should give learners the skills to be able to determine the modulus of elasticity and modulus of rigidity. Learners should also be able to interpret the results in order to understand the characteristics of the materials that they have analysed.

Learning aim C: Examine how dynamic engineering systems can be used to solve engineering problems

You could introduce learning aim C content by reviewing prior understanding of linear motion before giving learners a research task to investigate the various parameters associated with linear motion, prior to solving problems that relate to the theory. Leading on from this, you could introduce a range of dynamic parameters. For each of these, you could give learners a research task to help gain an understanding of parameters. Finally, you could introduce learners to a range of lifting machines, and how both linear and circular motion theories can be applied depending on the nature of the machine. Again, there is scope for individual investigation into a range of lifting machines. Learners should be able to analyse lifting machines in order to determine values such as torque, power and efficiency.

Learning aim D: Examine how fluid engineering systems can be used to solve engineering problems

Learning aim D introduces learners to fluid systems and immersed bodies. There is an opportunity within the teaching for both practical demonstrations and activities, especially when considering flow rates or methods to determine density. Initially, you could introduce learners to the procedures that need to be followed in order to calculate the hydrostatic pressure and thrust on submerged planes. Develop this understanding by considering methods to determine density. You could then use a virtual demonstration to explain how flow changes in a gradual tapering pipe, making reference to incompressible flow. You could give learners a range of activities that test their understanding of these concepts.

Finally, it would be appropriate to give learners an opportunity to analyse engineering problems that relate to fluid and immersed body systems and to perform the necessary procedures to derive solutions to posed problems.

Getting started

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

Unit 1: Mechanical Principles

Introduction

In delivering this unit, you have the opportunity to help learners develop the skills they will need to respond to a range of engineering challenges or scenarios. These will require them to apply their understanding of the concepts and topics found in the specification. You can approach this unit in a number of ways but it is likely that, once the underpinning knowledge has been addressed for each topic, learners can develop their knowledge by completing a range of different tasks and challenges to test their comprehension and understanding. This will enable you to gauge their capabilities and intervene where necessary. There are some opportunities for collaborative learning when considering some of the specification content. However, due to the nature of the assessment of the unit, learners should be given the opportunity to attempt challenges similar to those that they will encounter in the Pearson Set Assignment Brief.

Learning aim A: Examine how algebraic and trigonometric mathematical methods can be used to solve engineering problems

- Learning aim A content could be introduced by discussing learners' prior experiences when using algebraic methods to solve problems, along with their understanding of linear equations and straight-line graphs. This could be done either through discussion or through assessment. You could introduce learners to the method of plotting graphs from linear equations prior to giving learners a range of equations that they should plot for themselves. This will develop into using graphical methods to solve pairs of simultaneous equations. You could give learners scenarios where the direction of travelling objects is represented by linear equations, with learners needing to locate the intersect between the lines represented by each equation.
- You could then develop learners' abilities to apply algebraic concepts by introducing them to the factorisation of linear equations and subsequently quadratic equations. Learners should be taught how to apply the quadratic equation to find roots of an equation. You should provide learners with appropriate engineering contexts for the problems.
- Mensuration should be introduced by explaining the importance of circular measurements to learners, introducing radians as the unit of circular measurement, and explaining the advantages of using radians, especially with regards to finding arc lengths and areas of sectors. You could then expand on the motion of angular mensuration using the topic of angular rotation. Opportunities should be provided for learners to work collaboratively to gain experience of the correct application of theories to solve problems that relate to angular motion. You should consider a range of trigonometric functions, demonstrating to learners how to plot the waveforms of each, prior to giving learners opportunities to plot waveforms themselves.
- Once learners have understood each trigonometric function, introduce them to the sine and cosine rules. Learners can then apply the rules to solving problems, including those related to vectors. Learners should also review methods of determining surface areas of solids and related volumes prior to them having the opportunity to work individually on solving appropriate engineering problems.

Learning aim B: Examine how static engineering systems can be used to solve engineering problems

- Introduce learners to the basic principles of static engineering systems by relating the theory of vectors as covered in learning aim A. You should demonstrate to learners that forces can be represented using space and free body diagrams, applying the theory of vectors to determine resultant forces. Then, expand upon this understanding by introducing learners to moments and there will also be an opportunity for collaborative working in order to find moments of forces and the horizontal and vertical components of forces. Where possible, use practical demonstrations in order to show learners the conditions for static equilibrium, prior to explaining how these conditions can be arrived at. Give learners further opportunities for collaborative working to investigate systems. Expand upon the application of moments and conditions for equilibrium by introducing learners to simply supported beams. Introduce learners initially to the methods of resolving forces with point loadings before introducing uniformly distributed loads.
- This leads to content on loaded components. Begin by considering direct stress and strain, giving learners the knowledge of how to calculate values from given information. This can then be expanded to consider shear stress and strain. There are further opportunities for learners to work individually to solve problems before you demonstrate tensile strength and shear strength. This could be through practical demonstrations or virtually. Following investigation of these concepts, learners should be introduced to both the modulus of elasticity and the modulus of rigidity. Demonstrate how to derive values for these from values of stresses and strains. Give learners the opportunity to work independently to apply critical thinking skills so that they can solve non-routine problems that relate to structural systems.

Learning aim C: Examine how dynamic engineering systems can be used to solve engineering problems

- Begin by introducing topics found in learning aim C and by demonstrating the principles of linear motion through simulations. This could be used as a lead-in before learners begin a collaborative research activity to investigate kinetic parameters and then describe the link between each of these parameters when considering linear motion. Give learners a range of tasks to check their understanding of linear motion and uniform acceleration. Further collaborative working could then consider forces and related factors before learners present their findings to the wider group in the form of a presentation. Give learners opportunities to question their peers to determine depth of understanding. This will then inform any interventions you may need to make.
- Where possible, use practical demonstrations to introduce learners to potential and kinetic energy, making reference to conservation of energy. Create some problem-solving activities where learners will be able to apply their understanding of conservation of energy to unfamiliar situations. Once learners have a good understanding of the processes involved in the application of conservation of energy, you could expand upon Newton’s Laws of Motion and introduce the theory of conservation of momentum. This could initially be demonstrated prior to setting a collaborative task to solve a range of problems that relate to Newton’s Laws of Motion.
- Progress should now commence on the topic of angular motion, linking the knowledge of linear motion and angular mensuration. Discuss the differences between types of motion before setting learners an information gathering activity to investigate parameters related to angular motion. Also, demonstrate the procedures for determining values of parameters such as centripetal acceleration, along with more complex concepts such as rotational kinetic energy.

- Once learners have a good understanding of both linear and rotational movement within dynamic systems, draw together the various concepts and introduce learners to lifting machines. Give learners an investigation into the different types of lifting machines, and the types of motion involved with each. You should give learners an opportunity to consider aspects such as mechanical advantage and velocity ratio and then apply their understanding to solve problems that relate to raising loads through specified heights.
- To conclude, provide learners with challenges to solve which relate to linear and angular motion, including some that will require both types of motion to be considered in order to arrive at correct solutions.

Learning aim D: Examine how fluid engineering systems can be used to solve engineering problems

- Introduce learning aim D via a range of practical demonstrations to illustrate concepts including hydrostatic pressure and hydrostatic thrust. Demonstrate these, for example, through the use of a flat vertical surface within a tank of water and relate the concepts of equal and opposite forces being in equilibrium to demonstrate the hydrostatic thrust of water. This could be developed by considering hydrostatic pressure and centre of pressure; you could link this to applications such as dams where the variation in pressure leads to the thickness of the wall increasing with depth. Learners should also be equipped with the skills necessary to carry out calculations to determine the aforementioned quantities.
- With a good understanding of hydrostatic thrust, use further practical demonstrations to explain both the flotation method for determining relative densities and the Archimedes principle. This could lead into some small group collaborative working where learners carry out their own investigations with regards to density.
- There is further opportunity for concepts to be demonstrated, either virtually or, if available, through the use of suitable pipework with regards to flow in a gradually tapering pipe. Firstly, you could introduce learners to flow rates prior to considering flow velocities. It is important that learners have an understanding of incompressible fluid flow when considering flow in a gradually tapering pipe to make sure that they are able to apply concepts correctly when carrying out collaborative learning activities.

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

This unit links to:

- Unit 2: Delivery of Engineering Processes Safely as a Team
- Unit 3: Product Design and Manufacture in Engineering
- Unit 4: Applied Commercial and Quality Principles in Engineering
- Unit 57: Electrical and Electronic Principles

Resources

In addition to the resources listed below, publishers are likely to produce Pearson-endorsed textbooks that support this unit of the BTEC International qualifications in Engineering. Check the Pearson website (qualifications.pearson.com/endorsed-resources) for more information as titles achieve endorsement. If centres have access to the sample assessed materials (SAMs) from the Pearson website you will be able to view past papers for revision purposes.

Textbooks

Bird, J. *Engineering Mathematics*, Routledge, 2017, 9781138673595.
Popular textbook relating maths to its engineering contexts right from the beginning and throughout, with an abundance of practice exercises.

Bird, J. *Higher Engineering Mathematics,* 7th Edition, Routledge, 2014, 9780412662826.
Includes logarithms, trigonometry and angular measure.

Bird, J. and Ross, C. *Mechanical Engineering Principles*, Routledge, 2014, 9781138781573.
Includes stresses and strains, coplanar forces, simply supported beams, linear and angular motion, Newton's Laws of Motion, angular motion, lifting machines and hydrostatics.

Greer, A. *et al. BTEC National Mathematics for Technicians,* 4th Edition, Nelson Thornes, 2004, 9780748779499.
Includes solving linear equations, logarithms, area and volume, and trigonometry.

Moran, M.J., Shapiro, H.N. *et al. Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics, and Heat Transfer*, John Wiley & Sons, 2003, 9780471204909.
A survey of thermal systems engineering combines coverage of thermodynamics, fluid flow and heat transfer in one volume.

Nash, W. *Schaum's Outline of Statics and Mechanics of Materials*, McGraw-Hill Education, 1991, 9780070458963.
Good content regarding statics and mechanics of materials.

Videos

For a video about the law of conservation of energy, visit YouTube and search for Law of Conservation of Energy (Roller Coaster Demo).

For a video about conservation of momentum, visit YouTube and search for Richard Garriott Space Video Blog: Conservation of Momentum.

For a range of engineering based mathematical videos, visit YouTube and search for lectures on overviews of engineering mathematics.

For a range of video lectures on statics, visit YouTube and search for Statics: Lesson 1 – Intro and Newton's Laws, Scalars, and Vectors.

For a range of video lectures on fluid mechanics, visit YouTube and search for lectures on this topic.

Websites

Visit the Khan Academy website for a range of Math resources and tutorials.

Visit the STEMNET website for information and details about STEM ambassadors for support.

Visit the Maths for Engineering website for information on a wide range of mathematics for engineering topics.

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.