Unit 5006: Further Engineering Mathematics

Unit Code: Y/651/0860

Level: 5

Credits: 15

Introduction

The understanding of more advanced mathematics is important within an engineering and manufacturing sector curriculum to support and broaden abilities within the applied subjects at the core of all engineering programmes. Students are introduced to additional topics that will be relevant to them as they progress to the next level of their studies, advancing their knowledge of the underpinning mathematics gained in *Unit 4002: Engineering Mathematics*.

The unit will prepare students to analyse and model engineering/manufacturing situations using mathematical techniques. Among the topics included in this unit are: number theory, complex numbers, matrix theory, linear equations, numerical integration, numerical differentiation, and graphical representations of curves for estimation within an engineering/manufacturing context. Finally, students will expand their knowledge of calculus to discover how to model and solve engineering/manufacturing problems using first and second-order differential equations.

On successful completion of this unit, students will be able to use applications of number theory in practical engineering situations, solve systems of linear equations relevant to engineering/manufacturing applications using matrix methods, approximate solutions of contextualised examples with graphical and numerical methods, and review models of engineering and manufacturing systems using ordinary differential equations.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Use applications of number theory in practical engineering/manufacturing situations

LO2 Solve systems of linear equations relevant to engineering//manufacturing sector applications using matrix methods

LO3 Approximate solutions of contextualised examples with graphical and numerical methods

LO4 Review models of engineering/manufacturing systems using ordinary differential equations.

Essential Content

LO1 Use applications of number theory in practical engineering/manufacturing situations

Number theory:

Bases of a number (Denary, Binary, Octal, Duodecimal, Hexadecimal) and converting between bases

Types of numbers (Natural, Integer, Rational, Real, Complex)

The modulus, argument, and conjugate of complex numbers

Polar and exponential forms of complex numbers

The use of de Moivre's Theorem in engineering/manufacturing

Complex number applications e.g., electric circuit analysis, information, and energy control systems

Application of advanced numerical skills (Binary, dotted decimal notation) required to meet the defined specifications

Problem-solving and ensuring quality solutions to practical engineering/manufacturing situations relevant to the occupation/sector (e.g., operations, manufacturing, space, aeronautical, automation, electrical, electronics, mechanical, etc.); attention to detail and responsive to feedback; communication and presentation of solutions (including written, verbal, electronic format) to stakeholders, discussions, and negotiations.

LO2 Solve systems of linear equations relevant to engineering/manufacturing applications using matrix methods

Matrix methods:

Introduction to matrices and matrix notation

The process for addition, subtraction, and multiplication of matrices

Introducing the determinant of a matrix and calculating the determinant for a 2x2 and 3x3 matrix

Using the inverse of a square matrix to solve linear equations

Cramers Rule

Gaussian elimination to solve systems of linear equations (up to 3x3)

Eigenvalues and Eigenvectors.

LO3 **Approximate solutions of contextualised examples with graphical and numerical methods**

Graphical and numerical methods:

Standard curves of common functions, including quadratic, cubic, logarithm, and exponential curves

Systematic curve sketching knowing the equation of the curve

Using sketches to approximate solutions of equations

Numerical analysis using the bisection method and the Newton–Raphson method

Numerical integration using the mid-ordinate rule, the trapezium rule, and Simpson's rule

Examples of engineering scenarios using numerical methods for first-order and second-order differential equations; partial differential equations; homogeneous and non-homogeneous equations.

LO4 **Review models of engineering/manufacturing systems using ordinary differential equations**

Differential equations:

Formation and solutions of first-order differential equations (e.g., separation of variables)

Applications of first-order differential equations e.g., RC and RL electric circuits, Newton's laws of cooling, charge and discharge of electrical capacitors, and complex stresses and strains

Formation and solutions of second-order differential equations

Applications of second-order differential equations e.g., mass-spring-damper systems, information and energy control systems, heat transfer, automatic control systems and beam theory and RLC circuits

Introduction to Laplace transforms for solving linear ordinary differential equations

Applications involving Laplace transforms and inverse Laplace transforms. For example, electric circuit theory, load frequency control, harmonic vibrations of beams, reactor dynamics, and engine governors.

Continuous Professional Development (CPD) within the context:

Improve competencies in developing/using mathematical models of advanced engineering and manufacturing systems relevant to chosen occupation/sector through upskilling/reskilling opportunities (e.g., energy sustainability systems/models, climate change mathematical models for renewable technologies, advanced mathematics for Industry 4.0 technologies, applied mathematics for digitalisation, etc.).

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Use applications of number theory in practical engineering/manufacturing situations		
P1 Use addition and multiplication methods for numbers that are expressed in different base systems. **P2** Solve engineering/manufacturing problems using complex number theory. **P3** Perform arithmetic operations using the polar and exponential forms of complex numbers.	**M1** Solve problems using de Moivre's Theorem.	**D1** Test the correctness of a trigonometric identity using de Moivre's Theorem.
LO2 Solve systems of linear equations relevant to engineering/ manufacturing applications using matrix methods		
P4 Calculate the determinant of a set of given linear equations using a 3x3 matrix. **P5** Solve a system of three linear equations using Gaussian elimination.	**M2** Determine the solution to a set of given engineering linear equations using the Inverse Matrix Method for a 3x3 matrix.	**D2** Validate solutions for the given engineering linear equations using appropriate computer software.

Pass	Merit	Distinction
LO3 Approximate solutions of contextualised examples with graphical and numerical methods		
P6 Approximate solutions of sketched functions using a graphical estimation method. **P7** Calculate the roots of an equation using two different iterative techniques **P8** Determine the numerical integral of engineering functions using two different methods.	**M3** Solve engineering problems and formulate mathematical models using graphical and numerical integration.	**D3** Critically evaluate the use of numerical estimation methods, commenting on their applicability and the accuracy of the methods.
LO4 Review models of engineering/manufacturing systems using ordinary differential equations		
P9 Review and solve first-order differential equations related to engineering/ manufacturing systems. **P10** Formulate and solve second-order homogeneous and non-homogeneous differential equations related to engineering/manufacturing systems. **P11** Calculate solutions to linear ordinary differential equations using Laplace transforms.	**M4** Demonstrate how different models of engineering systems using first-order differential equations can be used to solve engineering/ manufacturing problems.	**D4** Critically evaluate first-order and second-order differential equations when generating the solutions to engineering/ manufacturing situations, using models of engineering systems.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Arfken G. B., Weber H. J., and harris F. E. (2011) *Mathematical methods for physicists: a comprehensive guide*. Academic press.

Bird J. (2021) *Higher Engineering Mathematics*. 9th Ed. Routledge.

Bird J. (2019) *Science and Mathematics for Engineering*. 6th Ed. Routledge.

Botelho F.S. (2021) *Functional Analysis, Calculus of Variations and Numerical Methods for Models in Physics and Engineering*. 1st Edition. CRC Press.

Chapra S. (2022) *Applied Numerical Methods with MATLAB for Engineers and Scientists.* 5th Edition. McGraw-Hill.

Chapra S. and Clough D. (2021) *Applied Numerical Methods with Python for Engineers and Scientists.* 1st Edition. McGraw-Hill.

Chapra S. and Canale R. (2020) *Numerical Methods for Engineers.* 8th Edition. McGraw-Hill.

Croft A., Davison R., Hargreaves M., and Flint J. (2017) *Engineering Mathematics.* 5th edition. Pearson Education.

Duffy D.G (2022) *Advanced Engineering Mathematics: A Second Course with MatLab.* 1st Edition. CRC Press.

Glyn J. and Dyke P. (2020) *Modern Engineering Mathematics.* 6th edition. Pearson.

Islam N., Singh S.B., Ranjan P., and Haghi A.K. (2021) *Mathematics Applied to Engineering in Action: Advanced Theories, Methods, and Models.* 1st Edition. CRC Press.

Made Easy Editorial Board (2022) *Engineering Mathematics for GATE 2023 and ESE 2023* (Prelims) – *Theory and Previous Year Solved Papers.* India: Made EASY Publications Pvt Ltd.

Ram M. (2021) *Recent Advances in Mathematics for Engineering.* CRC Press.

Teodorescu P., Stanescu N., and Pandrea N. (2013) *Numerical Analysis with Applications in Mechanics and Engineering.* Wiley-IEEE Press.

Ram M. (2020) *Mathematics in Engineering Sciences: Novel Theories, Technologies, and Applications.* 1st Edition. CRC Press.

Vick B. (2020) *Applied Engineering Mathematics.* CRC Press.

Singh K. (2011) *Engineering Mathematics Trough Applications*. Basingstoke, Palgrave Macmillan.

Stroud K.A. and Booth D.J. (2013) *Engineering Mathematics*. 7th Ed: Basingstoke, Palgrave Macmillan.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Annals of Mathematics

Computational Geometry

The Quarterly Journal of Mathematics

Journal of Geometry and Physics

Communications on Pure and Applied Mathematics

International Journal of Engineering Mathematics

Journal of Engineering Mathematics

Journal of Mathematical Physics

Journal of Computational and Engineering Mathematics

Links

This unit links to the following related unit:

Unit 4002: Engineering Mathematics