Unit 1: Analytical Methods for Engineers

Unit code: A/601/1401
QCF level: 4
Credit value: 15

Aim
This unit will provide the analytical knowledge and techniques needed to carry out a range of engineering tasks and will provide a base for further study of engineering mathematics.

Unit abstract
This unit enables learners to develop previous mathematical knowledge obtained at school or college and use fundamental algebra, trigonometry, calculus, statistics and probability for the analysis, modelling and solution of realistic engineering problems.

Learning outcome 1 looks at algebraic methods, including polynomial division, exponential, trigonometric and hyperbolic functions, arithmetic and geometric progressions in an engineering context and expressing variables as power series.

The second learning outcome will develop learners’ understanding of sinusoidal functions in an engineering concept such as AC waveforms, together with the use of trigonometric identities.

The calculus is introduced in learning outcome 3, both differentiation and integration with rules and various applications.

Finally, learning outcome 4 should extend learners’ knowledge of statistics and probability by looking at tabular and graphical representation of data; measures of mean, median, mode and standard deviation; the use of linear regression in engineering situations, probability and the Normal distribution.

Learning outcomes
On successful completion of this unit a learner will:
1. Be able to analyse and model engineering situations and solve problems using algebraic methods
2. Be able to analyse and model engineering situations and solve problems using trigonometric methods
3. Be able to analyse and model engineering situations and solve problems using calculus
4. Be able to analyse and model engineering situations and solve problems using statistics and probability.
1. Be able to analyse and model engineering situations and solve problems using algebraic methods

*Algebraic methods*: polynomial division; quotients and remainders; use of factor and remainder theorem; rules of order for partial fractions (including linear, repeated and quadratic factors); reduction of algebraic fractions to partial fractions

*Exponential, trigonometric and hyperbolic functions*: the nature of algebraic functions; relationship between exponential and logarithmic functions; reduction of exponential laws to linear form; solution of equations involving exponential and logarithmic expressions; relationship between trigonometric and hyperbolic identities; solution of equations involving hyperbolic functions

*Arithmetic and geometric*: notation for sequences; arithmetic and geometric progressions; the limit of a sequence; sigma notation; the sum of a series; arithmetic and geometric series; Pascal’s triangle and the binomial theorem

*Power series*: expressing variables as power series functions and use series to find approximate values eg exponential series, Maclaurin’s series, binomial series

2. Be able to analyse and model engineering situations and solve problems using trigonometric methods

*Sinusoidal functions*: review of the trigonometric ratios; Cartesian and polar co-ordinate systems; properties of the circle; radian measure; sinusoidal functions

*Applications*: angular velocity, angular acceleration, centripetal force, frequency, amplitude, phase, the production of complex waveforms using sinusoidal graphical synthesis, AC waveforms and phase shift

*Trigonometric identities*: relationship between trigonometric and hyperbolic identities; double angle and compound angle formulae and the conversion of products to sums and differences; use of trigonometric identities to solve trigonometric equations and simplify trigonometric expressions
3 Be able to analyse and model engineering situations and solve problems using calculus

*Calculus*: the concept of the limit and continuity; definition of the derivative; derivatives of standard functions; notion of the derivative and rates of change; differentiation of functions using the product, quotient and function of a function rules; integral calculus as the calculation of area and the inverse of differentiation; the indefinite integral and the constant of integration; standard integrals and the application of algebraic and trigonometric functions for their solution; the definite integral and area under curves

*Further differentiation*: second order and higher derivatives; logarithmic differentiation; differentiation of inverse trigonometric functions; differential coefficients of inverse hyperbolic functions

*Further integration*: integration by parts; integration by substitution; integration using partial fractions

*Applications of the calculus*: eg maxima and minima, points of inflexion, rates of change of temperature, distance and time, electrical capacitance, rms values, electrical circuit analysis, AC theory, electromagnetic fields, velocity and acceleration problems, complex stress and strain, engineering structures, simple harmonic motion, centroids, volumes of solids of revolution, second moments of area, moments of inertia, rules of Pappus, radius of gyration, thermodynamic work and heat energy

*Engineering problems*: eg stress and strain, torsion, motion, dynamic systems, oscillating systems, force systems, heat energy and thermodynamic systems, fluid flow, AC theory, electrical signals, information systems, transmission systems, electrical machines, electronics

4 Be able to analyse and model engineering situations and solve problems using statistics and probability

*Tabular and graphical form*: data collection methods; histograms; bar charts; line diagrams; cumulative frequency diagrams; scatter plots

*Central tendency and dispersion*: the concept of central tendency and variance measurement; mean; median; mode; standard deviation; variance and interquartile range; application to engineering production

*Regression, linear correlation*: determine linear correlation coefficients and regression lines and apply linear regression and product moment correlation to a variety of engineering situations

*Probability*: interpretation of probability; probabilistic models; empirical variability; events and sets; mutually exclusive events; independent events; conditional probability; sample space and probability; addition law; product law; Bayes’ theorem

*Probability distributions*: discrete and continuous distributions, introduction to the binomial, Poisson and normal distributions; use of the normal distribution to estimate confidence intervals and use of these confidence intervals to estimate the reliability and quality of appropriate engineering components and systems
## Learning outcomes and assessment criteria

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<th>Learning outcomes</th>
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<td><strong>On successful completion of this unit a learner will:</strong></td>
<td><strong>The learner can:</strong></td>
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| LO1 Be able to analyse and model engineering situations and solve problems using algebraic methods | 1.1 determine the quotient and remainder for algebraic fractions and reduce algebraic fractions to partial fractions  
1.2 solve engineering problems that involve the use and solution of exponential, trigonometric and hyperbolic functions and equations  
1.3 solve scientific problems that involve arithmetic and geometric series  
1.4 use power series methods to determine estimates of engineering variables expressed in power series form |
| LO2 Be able to analyse and model engineering situations and solve problems using trigonometric methods | 2.1 use trigonometric functions to solve engineering problems  
2.2 use sinusoidal functions and radian measure to solve engineering problems  
2.3 use trigonometric and hyperbolic identities to solve trigonometric equations and to simplify trigonometric expressions |
| LO3 Be able to analyse and model engineering situations and solve problems using calculus | 3.1 differentiate algebraic and trigonometric functions using the product, quotient and function of function rules  
3.2 determine higher order derivatives for algebraic, logarithmic, inverse trigonometric and inverse hyperbolic functions  
3.3 integrate functions using the rules, by parts, by substitution and partial fractions  
3.4 analyse engineering situations and solve engineering problems using calculus |
| LO4 Be able to analyse and model engineering situations and solve problems using statistics and probability | 4.1 represent engineering data in tabular and graphical form  
4.2 determine measures of central tendency and dispersion  
4.3 apply linear regression and product moment correlation to a variety of engineering situations  
4.4 use the normal distribution and confidence intervals for estimating reliability and quality of engineering components and systems. |
Guidance

Links

This unit can be linked with the core units and other principles and applications units within the programme. It will also form the underpinning knowledge for the study of further mathematical units such as Unit 35: Further Analytical Methods for Engineers, Unit 59: Advanced Mathematics for Engineering.

Entry requirements for this unit are at the discretion of the centre. However, it is strongly advised that learners should have completed the BTEC National unit Mathematics for Engineering Technicians or equivalent. Learners who have not attained this standard will require appropriate bridging studies.

Essential requirements

There are no essential resources for this unit.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.