

## Unit 22: Further Analytical Methods for Engineers

**Unit code: J/601/1465**

**QCF level: 5**

**Credit value: 15**

### ● Aim

This unit aims to further develop the analytical knowledge and techniques necessary to analyse and solve a variety of engineering situations and problems.

### ● Unit abstract

This unit has been designed to enable learners to use number systems, graphical and numerical methods, vectors, matrices and ordinary differential equations to analyse, model and solve realistic engineering problems.

Learners will use estimation techniques and error arithmetic to establish realistic results from experiments and general laboratory work. They will then consider the conversion of number systems from one base to another and the application of the binary number system to logic circuits. Complex numbers and their application to the solution of engineering problems are also studied.

Learners will look at the use of graphical techniques together with various methods of numerical integration (for example Simpson's rules) and estimation (for example Newton-Raphson). They will then go on to analyse and model engineering situations using vector geometry and matrix methods.

Finally, learners will study both first and second order differential equations and their application to a variety of engineering situations dependant upon the learner's chosen discipline.

### ● Learning outcomes

**On successful completion of this unit a learner will:**

- 1 Be able to analyse and model engineering situations and solve problems using number systems
- 2 Be able to analyse and model engineering situations and solve problems using graphical and numerical methods
- 3 Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods
- 4 Be able to analyse and model engineering situations and solve problems using ordinary differential equations.

## Unit content

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### 1 **Be able to analyse and model engineering situations and solve problems using number systems**

*Error arithmetic:* significant figures and estimation techniques; error arithmetic operations; systematic and random errors; application to experimentation and general laboratory work

*Number systems:* natural, integer, rational, reals, dinary, binary, octal and hexadecimal number systems; conversion from dinary to numbers of other bases and vice versa; two-state logic systems, binary numbers and logic gates, logic gate tables, application to logic circuits

*Complex numbers:* real and imaginary parts of complex numbers, complex number notation; Cartesian and polar forms; modulus, argument and complex conjugate; addition, subtraction, multiplication and division of Cartesian and polar forms; use of Argand diagrams; powers and roots and the use of de Moivre's theorem

*Engineering applications:* applications eg electric circuit analysis, phasors, transmission lines, information and energy control systems

### 2 **Be able to analyse and model engineering situations and solve problems using graphical and numerical methods**

*Graphical techniques:* Cartesian and polar co-ordinate systems and representation of complex number operations; vector representation; standard curves; asymptotes; systematic curve sketching; curve fitting; irregular areas and mean values of wave forms; use of phasor and Argand diagrams; application to engineering situations

*Numerical integral:* determine the integral of functions using mid-ordinate; trapezoidal and Simpson's rules

*Numerical estimation methods:* method of bisection; Newton-Raphson iteration method; estimates of scientific functions

### 3 **Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods**

*Vector notation and operations:* Cartesian co-ordinates and unit vectors; types of vector and vector representation; addition and subtraction; multiplication by a scalar; graphical methods

*Matrix operations and vectors:* carry out a range of matrix operations eg vectors in matrix form, square and rectangular matrices, row and column vectors, significance of the determinant, determinant for 2x2 matrix, the inverse of a 2x2 matrix; use Gaussian elimination to solve systems of linear equations (up to 3x3)

*Vector geometry:* determine scalar product, vector product, angle between two vectors, equation of a line, norm of a vector, dot and cross products; apply vector geometry to the solution of engineering problems eg velocity vector and mechanisms, acceleration vector and mechanisms, forces in static frameworks and structures, evaluation of static joint structures using dot product, phasors

### 4 **Be able to analyse and model engineering situations and solve problems using ordinary differential equations**

*First order differential equations:* engineering use; separation of variables; integrating factor method, complementary function and particular integral

*Numerical methods for first order differential equations:* need for numerical solution; Euler's method; improved Euler method; Taylor series method

*Application of first order differential equations:* applications eg RC and RL electric circuits, time constants, motion with constant and variable acceleration, Fourier equation for heat transfer, Newton's laws of cooling, charge and discharge of electrical capacitors, complex stress and strain, metrology problems

*Second order differential equations:* engineering use; arbitrary constants; homogeneous and non-homogeneous linear second order equations

*Application of second order differential equations:* applications eg RLC series and parallel circuits, undamped and damped mechanical oscillations, fluid systems, flight control laws, mass-spring-damper systems, translational and rotational motion systems, thermodynamic systems, information and energy control systems, heat transfer, automatic control systems, stress and strain, torsion, shells, beam theory

*Engineering situations:* applications eg heat transfer, Newton's laws, growth and decay, mechanical systems, electrical systems, electronics, design, fluid systems, thermodynamics, control, statics, dynamics, energy systems, aerodynamics, vehicle systems, transmission and communication systems

## Learning outcomes and assessment criteria

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO1 Be able to analyse and model engineering situations and solve problems using number systems	1.1 use estimation techniques and error arithmetic to establish realistic results from experiment  1.2 convert number systems from one base to another, and apply the binary number system to logic circuits  1.3 perform arithmetic operations using complex numbers in Cartesian and polar form  1.4 determine the powers and roots of complex numbers using de Moivre's theorem  1.5 apply complex number theory to the solution of engineering problems when appropriate
LO2 Be able to analyse and model engineering situations and solve problems using graphical and numerical methods	2.1 draw graphs involving algebraic, trigonometric and logarithmic data from a variety of scientific and engineering sources, and determine realistic estimates for variables using graphical estimation techniques  2.2 make estimates and determine engineering parameters from graphs, diagrams, charts and data tables  2.3 determine the numerical integral of scientific and engineering functions  2.4 estimate values for scientific and engineering functions using iterative techniques
LO3 Be able to analyse and model engineering situations and solve problems using vector geometry and matrix methods	3.1 represent force systems, motion parameters and waveforms as vectors and determine required engineering parameters using analytical and graphical methods  3.2 represent linear vector equations in matrix form and solve the system of linear equations using Gaussian elimination  3.3 use vector geometry to model and solve appropriate engineering problems

<b>Learning outcomes</b>  <b>On successful completion of this unit a learner will:</b>	<b>Assessment criteria for pass</b>  <b>The learner can:</b>
LO4 Be able to analyse and model engineering situations and solve problems using ordinary differential equations	4.1 analyse engineering problems and formulate mathematical models using first order differential equations 4.2 solve first order differential equations using analytical and numerical methods 4.3 analyse engineering problems and formulate mathematical models using second order differential equations 4.4 solve second order homogeneous and non-homogenous differential equations 4.5 apply first and second order differential equations to the solution of engineering situations.

## Guidance

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### Links

This unit builds on and can be linked to *Unit 1: Analytical Methods for Engineers* and can provide a foundation for *Unit 59: Advanced Mathematics for Engineering*.

### Essential requirements

There are no essential requirements for this unit.

### Employer engagement and vocational contexts

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