Unit 300 Advanced engineering analysis

Unit summary

This unit is about the advanced techniques needed to analyse systems in various engineering disciplines. The unit provides the advanced knowledge required to solve partial differential equations, optimise engineering systems and apply random processes and spectral analysis.

Aims

The unit aims to enable the candidate to apply analytical techniques to engineering systems design and problem solving.

Prerequisites

It is expected that candidates will have competence in mathematics at a level exemplified by the Graduate Diploma syllabus 9107-224 Advanced mathematical techniques for engineering applications or equivalent.

Learning outcomes

There are **three** outcomes to this unit. The candidate will be able to:

- Solve engineering problems by applying partial differential equations
- Apply optimisation techniques to engineering-problem solving
- Use random processes and apply spectral analysis to data filtering and system identification problems

Guided learning hours

It is recommended that 300 hours should be allocated for this unit. 120 of those hours are actual taught hours. This may be on a full time or part time basis.

Key Skills

No Key Skills were identified for this unit.

Occupational Standards

This unit has been mapped to the following National Occupational Standards:

1.1.1 Identify the requirements of clients for engineering products or processes
1.1.2 Produce specifications for engineering products or processes
1.2.1 Identify and define areas of research
1.3.2 Evaluate the results of research
1.4.4 Evaluate designs for engineering products or processes
2.1.1 Determine the production requirements of engineering products and processes
2.2.2 Solve production problems with engineering solutions
2.3.2 Evaluate the production process
3.2.2 Solve installation problems with engineering solutions
4.1.1 Determine the operational requirements of engineering products or processes
4.1.2 Specify operational methods and procedures to achieve operational requirements
4.2.2 Solve operational problems with engineering solutions
6.1.1 Analyse the risks arising from engineering products and processes
6.2.1 Assure the quality of engineering products or processes
7.2.3 Evaluate projects
8.1.1 Maintain and develop own engineering expertise

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Outcome 1 Solve engineering problems by applying partial differential equations

Knowledge requirements
The candidate knows how to:

1 apply partial differential equations in civil, electrical and mechanical engineering

2 systems

3 classify partial differential equations as parabolic, hyperbolic or elliptical

4 identify Cartesian, cylindrical and spherical co-ordinate forms

5 apply analytic solution methods using trial functions, separation of variables (including Bessel and Legendre functions as appropriate), Laplace and Fourier transforms

6 use finite-difference methods to solve partial differential equations

- a approximation of derivatives
- b explicit and Crank-Nicholson implicit methods
- c numerical stability

7 apply methods for solving linear equations resulting from finite-difference methods

- a direct solution, including Cramer's rule and Gaussian elimination
- b iterative methods, including relaxation and Gauss-Seidel methods

8 solve problems using the method of lines

9 use the method of characteristics for hyperbolic equations

10 use the finite-element method at an introductory level

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Outcome 2 Apply optimisation techniques to engineering-problem solving

Knowledge requirements
The candidate knows how to:

1 describe the characteristics of functions used in optimisation including combinatorial, unimodal and multi-modal functions, single-variable and multi-variable functions, functions with constraints, local and global extremes of functions

2 formulate and solve constrained optimisation problems by the simplex method of linear programming

3 use Fibonacci, golden section and Brent's single-variable search methods to solve optimisation problems

4 apply multi-variable methods to optimisation problems using gradient methods

- a steepest descent
- b conjugate gradient
- c Newton's variable metric techniques

5 apply the penalty-function method, complex method of Box and the Kuhn-Tucker conditions to functions with inequality constraints

6 solve optimisation problems by heuristic search methods, random-number generation and objective functions

7 apply the simulated-annealing method to combinatorial problems

8 apply genetic algorithms, coding, reproduction and cross-over mutation to solve optimisation problems

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Outcome 3 Use random processes and apply spectral analysis to data filtering and system identification problems

Knowledge requirements
The candidate knows how to:

1 describe the role of random processes in the testing and analysis of engineering systems

2 recognize the engineering applications of random processes in random vibrations, electrical circuits and communications

3 derive the principal functions used to characterise random processes and the dynamic response of engineering systems

4 recognise the characteristics of random processes including stationary and non-stationary processes, ergodic processes, probability distributions for single and multiple random variables, auto- and cross-correlation functions, spectral and cross-spectral density

5 determine the response of engineering systems to stochastic inputs

6 recognise white noise, wide-band, narrow-band, Gaussian and pseudo-random binary signal (PRBS) noise sources

7 describe the dynamic characteristics of linear systems using impulse-response functions, convolution integral and frequency response-functions

8 explain the operation of fast Fourier transform algorithms

9 describe random input-output relationships for linear systems, power spectra and cross-spectra for single-input and two-input systems, coherence functions

10 describe and compare analogue and digital methods of spectral-density measurement

11 undertake digital spectral analysis in signal sampling, aliasing, data windows, spectral leakage, frequency smoothing and fast Fourier transform

12 use fast Fourier transform for power spectra estimates

13 apply the techniques to data filtering and system identification problems

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Recommended reading list

Core texts	Author(s)	Publisher	ISBN
Advanced Engineering Mathematics - Section A	Kreyszig	John Wiley and Sons	047133328X
Advanced Engineering Mathematics	James	Addison-Wesley	201565196
Advanced Engineering Mathematics	Kreyszig	John Wiley and Sons	947133328X
Advanced Modern Engineering Mathematics	James	Addison Wesley	0201565196
Fourier Series and Boundary Value Problems	Brown	McGraw-Hill Education	0072325704
Numerical Methods for Mathematics, Science and Engineering	Mathews	Prentice Hall	0136249906
Numerical Methods for Partial Differential Equations	Ames	Nelson	0120567601
Schaum's Outline of Partial Differential Equations	Duchateau	McGraw-Hill Education	0070178976
Advanced Engineering Mathematics - Section B	Kreyszig	John Wiley and Sons	047133328X
Advanced Modern Engineering Mathematics	James	Addison Wesley	0201565196
An Introduction to Genetic Algorithms for Scientists and Engineers	Coley	World Scientific	9810236026
Other useful texts			
Basic Optimisation Methods	Bunday	Hodder Arnold	0713135069
Numerical Methods for Mathematics, Science and Engineering	Mathews	Prentice Hall	0136249906
Operations Research: An Introduction	Taha	Prentice Hall	0131876597
Analogue and Digital Signal Processing - Section C	Baher	John Wiley and Sons	0471923427
Detection of Signals in Noise	McDonough, Whalen	Academic Press	0127448527
Digital Signal Processing: Concepts and Applications	Mulgrew	Palgrave Macmillan	0333963563
Introductory Digital Signal Processing with Computer Applications	Lynn, Fuerst	John Wiley and Sons	0471976318
Probabilistic Methods of Signal and System Analysis	Cooper, McGillen	Oxford University Press	0195123549