Unit 302 Computational mechanics using finite element method

Unit summary
This unit is about the fundamental principles of the Finite Element Method as applied to mechanical and civil engineering.

Aims
To provide the candidate with a sound foundation in Finite Element Analysis.

Prerequisites
Candidates should have studied Mathematics for engineering to first degree level, or equivalent, incorporating an introduction to numerical methods for the solution of systems of equations. They will normally have previous study experience in courses in Mechanics of solids and/or The analysis of engineering structures.

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

- Apply and solve constitutive equations used in Finite Element Analysis (FEA)
- Apply strain-displacement formulations used in Finite Element Analysis
- Define material behaviour within Finite Element Analysis
- Apply solution algorithms and interpret results
- Analyse special case applications

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
1.3.1 Undertake research into engineering products or processes
1.3.2 Evaluate the results of research
1.4.4 Evaluate designs for engineering products or processes
2.2.2 Solve production problems with engineering solutions
4.1.1 Determine the operational requirements of engineering products or processes
4.2.2 Solve operational problems with engineering solutions
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 Apply and solve constitutive equations used in Finite Element Analysis (FEA)

Knowledge requirements
The candidate knows how to:

1 formulate strain displacement relationships, shape functions and element stiffness matrices

2 apply local-global co-ordinate transformations

3 apply boundary conditions, constraints and loads

4 define equivalent nodal forces for

- a body forces
- b concentrated loads
- c distributed loads
- d thermal loads

5 form global stiffness matrix and load vectors

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Outcome 2 Apply strain-displacement formulations used in Finite Element Analysis

Knowledge requirements
The candidate knows how to:

1 formulate strain-displacement for 1st-order elements
   - a constant strain triangle
   - b bilinear quadrilateral

2 formulate strain-displacement for 2nd-order elements
   - a linear strain triangle
   - b quadratic quadrilateral
   - c Serendipity family of elements
   - d Isoparametric elements

3 use Jacobian *n*-point Gauss quadrature numerical integration to form element stiffness matrices and equivalent nodal forces

4 analyse simple beam elements
   - a Timoshenko modified beam element
   - b planar frame element

5 analyse plate and shell elements

6 use interface elements for geometric non-linearities and crack-tip elements for fracture problems

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Outcome 3 Define material behaviour within Finite Element Analysis

Knowledge requirements
The candidate knows how to:

1 recognise degrees of material behaviour
- a isotropic
- b transversely isotropic
- c orthotropic
- d fully anisotropic

2 define material behaviour using
- a Young's moduli
- b shear moduli
- c Poisson's ratios
- d thermal expansion coefficients

3 define various types of non-linear materials
- a elasto-plastic
- b Drucker-Prager
- c foam
- d rubber
- e soil

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Outcome 4 Apply solution algorithms and interpret results

Knowledge requirements
The candidate knows how to:

1 solve linear and non-linear systems using
   - a Gaussian Elimination Gauss-Seidel iteration relaxation techniques
   - b Gauss-Seidel iteration
   - c Relaxation techniques

2 recognise
   - a banded storage
   - b sykline storage
   - c frontal solvers
   - d effects of nodal and element numbering

3 determine convergence and completeness requirements

4 determine inter-element compatibility using the patch test

5 interpret the quality of results using
   - a element quality test
   - b discretisation error
   - c global measures of error
   - d h-refinement
   - e p-refinement

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Outcome 5 Analyse special case applications

Knowledge requirements
The candidate knows how to:

1 analyse special case applications
   a axisymmetric
   b plane stress
   c plane strain
   d dynamic
   e thermal

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Recommended reading list

Core texts	Author(s)	Publisher	ISBN
A Microcomputer Introduction to the Finite Element Method	Mohr, Milllner	Heinemann	043491262x
Applied Numerical Analysis	Gerald, Wheatley	Addison-Wesley	0201474352
Finite Element Modelling for Stress Analysis	Cook	John Wiley & Sons Inc	0471107743
Finite Elements in Solids and Structure	Astley	Kluwer Academic	0412441608