Engineering Tripos Part IIA, 3D7: Finite Element Methods, 2018-19

Module Leader

Dr J Li [1]

Lecturers

Dr J Li and Prof G Wells

Lab Leader

Dr C Abadie

Timing and Structure

Lent term. 16 lectures and coursework.

Aims

The aims of the course are to:

- Provide an introduction to the finite-element (FE) method, which is widely used to obtain numerical solutions to engineering problems.
- Explain the key ideas of the FE approach, covers its theoretical foundations, and presents some illustrative applications.

Objectives

As specific objectives, by the end of the course students should be able to:

- Develop the weak form of a governing equation for various problems.
- Explain the difference between strong weak formulations.
- Compute shape functions in one, two and three dimensions for different elements.
- Obtain the stiffness and mass matrices and the right-hand side vector for different elements.
- Explain the ideas and motivations behind isoparametric formulations.
- Apply numerical integration on different finite elements
- Assemble the stiffness and mass matrices for a mesh.
- Explain how to apply various loadings and boundary conditions.
- Generate suitable meshes for different problems.
- Set up a finite element mesh, apply appropriate boundary and solve the resulting system in a finite element program.
- Appreciate sources of errors associated with finite element analysis.
- Explain key features of different methods for time-dependent problems.

Content

Introduction to finite element analysis (1L Prof G.N. Wells)

- Overview and key ideas

- Modelling and applicability

Elastic rods and beams (3L Dr G.N. Wells)

- Strong and weak equations of equilibrium for rods
- Linear shape functions in one dimension
- Assembly and application of boundary conditions
- Construction of higher-order shape functions
- Euler beams and Hermitian shape functions

Membranes, heat conduction and elasticity in two and three dimensions (8L Dr J Li)

- Strong and weak formulations for membranes and heat conduction
- Shape functions for two and three dimensional elements
- Isoparametric mapping and numerical integration
- Application of boundary conditions
- Assembly of element matrices and vectors
- Stability considerations
- Generalisation to elasticity
- Aspects of solid modelling and meshing

Modelling issues (2L Prof G.N. Wells)

- Practical issues: element selection, what can go wrong, when does it not work?
- Errors and convergence
- Stress recovery and post-processing

Time dependent problems (2L Prof G.N. Wells)

Strategies for time-dependent problems

Coursework

Use of a finite-element package to solve a stress-analysis problem related to the experiment performed in Module 3C7.

[Coursework Title]

Learning objectives:

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Practical information:

- Sessions will take place in [Location], during week(s) [xxx].
- This activity [involves/doesn't involve] preliminary work ([estimated duration]).
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Full Technical Report:

Students will have the option to submit a Full Technical Report.

Booklists

Please see the Booklist for Part IIA Courses [2] for references for this module.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

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[1] mailto:jl305@cam.ac.uk
[2] https://www.vle.cam.ac.uk/mod/book/view.php?id=364091&chapterid=46621
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