

## **Engineering Tripos Part IIA, 3D7: Finite Element Methods, 2019-20**

### **Module Leader**

[Dr F Cirak](#) [1]

### **Lecturers**

Dr F Cirak and Prof G Wells

### **Lab Leader**

[Dr F Cirak](#) [1]

### **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, cover its theoretical foundations, and present some illustrative applications.

### **Objectives**

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

- Develop the weak form of the governing equation for various problems.
- Explain the difference between strong and 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 idea and motivation 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 conditions 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 Dr 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

### **Heat conduction and elasticity in two and three dimensions (8L Dr F Cirak)**

- Strong and weak formulations for 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 Dr 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 Dr 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.

### **Computational Stress Analysis**

#### Learning objectives:

- Quantify the choice of elements on the obtained results.
- Identify the importance of the choice of boundary conditions.
- Compare finite element results with experimental and analytical results.

#### Practical information:

- Sessions will take place in DPO, during weeks [2-5].
- This activity involves preliminary work (1.5 hours).
- Sign up: <http://to.eng.cam.ac.uk/teaching/apps/cuedle/index.php?context=3D7> [2]

#### Full Technical Report:

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

## **Booklists**

Please see the [Booklist for Part IIA Courses](#) [3] for references for this module.

## **Examination Guidelines**

Please refer to [Form & conduct of the examinations](#) [4].

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## **Links**

[1] <mailto:fc286@cam.ac.uk>

[2] <http://to.eng.cam.ac.uk/teaching/apps/cuedle/index.php?context=3D7>

[3] <https://www.vle.cam.ac.uk/mod/book/view.php?id=364091&chapterid=46621>

[4] <https://teaching22-23.eng.cam.ac.uk/content/form-conduct-examinations>