

## **Engineering Tripos Part IIA, 3D7: Finite Element Methods, 2021-22**

### **Module Leader**

[Prof F Cirak](#) [1]

### **Lecturers**

Prof F Cirak, Dr B Liu

### **Lab Leader**

[Prof 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 B Liu)**

- Overview and key ideas

- Modelling and applicability

### **Elastic rods and beams (3L Dr B Liu)**

- Strong and weak equations of static 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 Prof 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 B Liu)**

- Model analysis and critical time step
- Error estimates and convergence of finite element method

### **Time dependent problems (2L Dr B Liu)**

- Strong and Weak formulation for time-dependent problems
- Consistent and lumped mass matrix
- Explicit and Implicit time integration

## **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.
- Explore the influence of mesh refinement on computed results.

#### Practical information:

- The coursework can be completed remotely. Support session will be held online.
- This activity involves the installation/configuration of software. Instructions will be provided.
- 3C7 experimental data can be obtained from the Lab Leader.

#### Full Technical Report:

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

## Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

## Examination Guidelines

Please refer to [Form & conduct of the examinations](#) [2].

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## Links

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

[2] <https://teaching24-25.eng.cam.ac.uk/content/form-conduct-examinations>