Engineering Tripos Part IIB, 4M12: Partial Differential Equations & Variational Methods (shared with IIA), 2019-20

Module Leader

Dr J S Biggins [1]

Lecturers

Dr J S Biggins and Prof P Davidson [2]

Timing and Structure

Lent term. 16 lectures (including examples classes). Assessment: 100% exam

Aims

The aims of the course are to:

- provide an introduction to the various classes of PDE and the physical nature of their solution
- demonstrate how variational calculus can be used to derive both ordinary and partial differential equations, and also how the technique can be used to obtain approximate solutions to these equations

Objectives

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

- understand the various types of PDE and the physical nature of their solutions.
- understand various solution methods for PDEs and be able to apply these to a range of problems.
- understand the formulation of various physical problems in terms of variational statements
- estimate solutions using trial functions and direct minimisation;
- calculate an Euler-Lagrange differential equation from a variational statement, and to find the corresponding natural boundary conditions;
- perform vector manipulations using suffix notation.

Content

Partial differential equations (PDEs) occur widely in all branches of engineering science, and this course provides an introduction to the various classes of PDE and the physical nature of their solution. The second part of the course demonstrates how variational calculus can be used to derive both ordinary and partial differential equations, and also how the technique can be used to obtain approximate solutions to these equations. The final section on the summation convention provides a powerful mathematical tool for the manipulation of equations that arise in engineering analysis

Suffix notation and the summation convention (2L Dr J S Biggins)

Index notation for scalar, vector, and matrix products, and for grad, div and curl. Applications including Stokes' theorem and the divergence theorem.

Variational methods in engineering analysis (6L DrJ S Biggins)

Introduction to variational calculus. Functionals and their first variation. Derivation of differential equations and boundary conditions from variational principles. The Euler-Lagrange equations. The effect of constraints. Applications in mechanics, optics, stress analysis, and optimal control.

Partial Differential Equations (8L Prof. P. A. Davidson)

What is a PDE? Classification of PDEs: elliptic/parabolic/hyperbolic types. Canonical examples of each type: Laplace/diffusion/wave equations. solving the diffusion equation. Solving the wave equation. Solving the Laplace equation.

Booklists

Please see the Booklist for Group M Courses [3] for references for this module.

Examination Guidelines

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

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [5] 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.

IA2

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

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.

E3

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

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

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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Links
[1] mailto:jsb56@cam.ac.uk
[2] mailto:jsb56@cam.ac.uk, pad3@cam.ac.uk
[3] https://www.vle.cam.ac.uk/mod/book/view.php?id=364101&chapterid=56231
[4] https://teaching25-26.eng.cam.ac.uk/content/form-conduct-examinations
[5] https://teaching25-26.eng.cam.ac.uk/content/uk-spec