Engineering Tripos Part IA, 1P2: Materials, 2025-26

Course Leader

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Timing and Structure

Michaelmas: 1 lecture (wk 8); Christmas vacation: "Teach Yourself" Examples Paper; Lent (wks 1-8): 13 lectures (1 or 2 per week); Easter: 4 lectures (2 or 3 per week)

Prerequisites

STEM-Start Problems (separate PDF): Materials

Aims

The aims of the course are to:

- Introduce the material properties and failure mechanisms most relevant to mechanical design and engineering applications.
- Relate properties to atomic, molecular and microstructural features, using appropriate mathematical models.
- Enable analysis of material performance in mechanical design, including strategies for material and process selection

Objectives

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

- Define the main mechanical properties of materials and how they are measured experimentally, and use them in design for stiffness and avoidance of failure
- Analyse the stress-strain response of simple geometries under uniform mechanical and thermal loads, distinguishing between true and nominal stress and strain
- Describe the atomic and microstructural characteristics which control the mechanical properties of engineering materials, and to interpret material property charts
- Describe and interpret simple concepts of atomic bonding, packing and crystallography of materials,

including first principles estimates of density
- Explain briefly the origin of the elastic modulus for each class of engineering materials (metals, ceramics, polymers) and analyse the moduli of composites
- Describe the mechanisms for plastic flow in metals, and the ways in which the strength can be enhanced via composition and processing
- Describe the mechanisms of fracture and fatigue in each class of engineering materials
- Apply fracture mechanics analysis to design against fracture and fatigue in metals, and apply Weibull failure statistics for design in ceramics
- Describe briefly the mechanisms of friction and wear in engineering
- Understand and apply a systematic strategy for materials selection for a given component, using material property charts (e.g. stiffness and strength of beams at minimum weight)
- Choose primary shaping process from process attribute charts, and estimate the cost of manufacture for batch processing
- Understand the environmental impact of materials in the life cycle of products

Content

Introduction (1L, Prof. AE Markaki)

Classes of engineering materials and their applications; material properties in design. *(1) Chap. 1,2; (2) Chap. 30; (3) Chap. 27*

Introductory Solid Mechanics and Stress Analysis: Elastic and Plastic Properties of Materials (3L), Dr M Seita)

- Introductory solid mechanics (online-only): elasticity/plasticity in design and manufacture; elastic and plastic properties: definition and measurement - Young's modulus, yield strength, tensile strength, ductility and hardness; mechanical property data and material property charts; Hooke's Law and 3D stress-strain; nominal and true stress and strain. *(1) Chap. 4,6; (2) Chap. 3,7,8,11,12,31; (3) Chap. 4-6; (4) Chap. 7*
- Analysis of stress and strain: constrained deformation, thermal stress. *(1) Chap. 4,12; (2) Chap. 3; (4) Chap. 7*

Microstructural Origin and Manipulation of Material Properties (4L + online "Guided Learning Unit", Dr M Seita)

- Introduction to microstructure and crystallography, and physical basis of density (online "teach yourself" Guided Learning Unit). *(1) Ch 4, GLU1.*
- Physical basis of elastic modulus: atomic/molecular structure and bonding. *(1) Chap. 4; (2) Chap. 4-6; (4) Chap. 2-4*
- Microstructual origin and manipulation of elastic properties: foams and composites. *(1) Chap. 4; (2) Chap. 6*
- Physical basis of plasticity and yielding: ideal strength, dislocations in metals; failure of polymers. *(1) Chap. 6; (2) Chap. 9; (4) Chap. 8*
- Microstructural orgin and manipulating plastic properties: strengthening mechanisms in metals. *(1) Chap. 6,19; (2) Chap. 10; (4) Chap. 8,12*
- Overview of microstructural length-scales. *(1) 4th edn, App C*

Fracture and Fatigue of Materials, Friction and Wear (5L, Prof AE Markaki)

- Toughness, fracture toughness and fatigue fracture.
- Micromechanisms of brittle and ductile fracture, and of fatigue, in metals.
- Analysis of fracture and fatigue in design.
- Weibull statistics for ceramic fracture.
- Micromechanisms of friction and wear in materials.

(1) Chap. 8-11; (2) Chap. 13-19; (3) Chap. 18,23; (4) Chap. 9

Materials in Design: Material and Process Selection, and Environmental Impact of Materials (4L, Prof. J

Cullen)

- Environmental impact and life cycle analysis of materials. *(1) Chap. 20*
- Material selection in design; stiffness-limited and strength-limited component design (online-only). *(1) Chap. 2,3,5,7; (2) Chap. 3,7; (4) Chap. 7*
- Further material selection: effect of shape, and multiple constraints (online-only). *(1) Chap. 5,7*
- Selection of manufacturing process and cost estimation for batch processes (online-only). *(1) Chap. 18*

REFERENCES

(1) ASHBY, M., SHERCLIFF, H. & CEBON, D. MATERIALS: ENGINEERING, SCIENCE, PROCESSING AND DESIGN (3rd or 4th edition)
(2) ASHBY, M.F. & JONES, D.R.H ENGINEERING MATERIALS 1
(3) ASHBY, M.F. & JONES, D.R.H ENGINEERING MATERIALS 2
(4) CALLISTER, W.D. MATERIALS SCIENCE & ENGINEERING: AN INTRODUCTION

Booklists

Please refer to the Booklist for Part IA 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 [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.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

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.

D1

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.

D3

Identify and manage cost drivers.

D5

Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal.

S3

Understanding of the requirement for engineering activities to promote sustainable development.

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.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

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

P4

Understanding use of technical literature and other information sources.

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.

US4

An awareness of developing technologies related to own specialisation.

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