[node:field-syllabus-course-year:parent:name], Engineering Tripos Part IA, 2025-26

Course Leader

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Lecturer

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Timing and Structure

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

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)

- Brittle fracture: stress concentration and crack-initiated fracture, strain energy release rate and stress intensity factor.
- Ductile fracture: crack tip plasticity, fracture toughness of engineering materials, micromechanisms of brittle and ductile fracture.
- Weibull statistics for ceramic fracture.
- Fatigue fracture: low and high cycle fatigue, characterisation of fatigue crack propagation, failure of pressure vessels.
- 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].

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