Engineering Tripos Part IA, 1P2: Structures, 2024-25

Course Leader

Prof Julian Allwood [1]

Lecturer

Prof A McRobie [2]

Lecturer

Prof Julian Allwood [1]

Timing and Structure

Weeks 1-8 Michaelmas term and weeks 1-8 Lent term. 24 lectures. Michaelmas Term lectures will not be recorded; rather, the Moodle page will contain pre-prepared recordings of the material. Lent Term lectures will be recorded.

Aims

The aims of the course are to:

- Inform students of the key role of structures in different branches of engineering
- Illustrate the way in which structural engineers use the principles of structural mechanics to understand the behaviour of structures and so to design structures in order to meet specified requirements
- Examine in detail certain simple structural forms, including triangulated frameworks, beams and cables; to understand how such structures carry applied loads, how they deform under load, and how slender members may buckle

Objectives

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

- Describe, qualitatively, the way in which different kinds of structure (frameworks, beams, cables, pressure vessels, etc.) support the loads that are applied to them.
- Analyse the limiting equilibrium conditions of bodies in frictional contact.
- Determine the axial force in any member of a statically determinate pin-jointed framework, making use of structural symmetry and of the principle of superposition when appropriate
- Explain and determine the shape of an inextensional cable subject to concentrated and distributed loads, as well as the tension distribution and support reactions.
- Test the stability of a simple, statically determinate arch structure
- Determine the displacement of any point of a pin-jointed framework subject to prescribed bar extensions by using a displacement diagram
- Understand and apply the equation of virtual work for pin-jointed frameworks and know how to choose appropriate equilibrium and compatible sets
- Construct bending-moment and shearing-force diagrams for simple beam structures, and to explain the relationship between them.
- Explain curvature, and how it changes in an elastic beam when the bending moment changes.
- Explain and compute the geometry of deflection of an initially straight beam on account of curvature within

it.
- Explain and compute the detailed distribution of bending stress in the cross-section of an elastic beam having a symmetrical cross-section, and sustaining a bending moment.
- Explain and compute the distribution of shearing stress in the cross-section of an elastic beam having a symmetrical cross-section, and sustaining a shearing force.
- Determine the buckling load of a column, and be able to approach the design of columns accounting for the effects of yielding of the material and geometric imperfections.

Content

Introduction and Aims of the Course (1 Lecture)

1. External forces (3L)

Equilibrium of point forces, moments and couples

- Forces as vectors
- Moments as vectors
- Couples [3, Sect 1/1-1/5, 1/7-2/5]
- Resultants [3, Sect 2/6]
- Equilibrium [3, Sect 2/6, 3/3]
- Accuracy in structural mechanics

Distributed loads and friction forces

- Forms of distributed load [3, Sect 1/6, 5/1- 5/3, 5/9]
- Contact forces (without friction)
- Contact forces (with friction) [3, Sect 6/1-6/3, 6/8]
- Distributed friction

Supports and free-body diagrams

- Pin-joints
- Roller supports
- Built-in or ‘encastré’ supports
- Catalogue of support options
- Free-body diagrams [3, Sect 3/1- 3/2, 3/4]

2. Internal forces (3L)

Pin-jointed trusses

- Method of joints [3, Sect 4/3]
- Method of sections [3, Sect 4/4]
- Some simplifications in analysing planar pin-jointed trusses
- Superposition
- Symmetry

Shear forces and bending moments

- Beams with transverse loading
- Free-body diagrams with shear forces and bending moments
- Arches [4, Sect 5.1, 5.6], [7, Ch. 5]

Sress

- Two-dimensional plane stress in thin-walled shells
- Thin-walled shells with uniform stress

3. Deflection (5L)

Cables and compatibility

- Cables subjected to concentrated loads
- Cables subjected to distributed loads

Deflection of members in pin-jointed frames

- Statically determinate frames
- Strains, Hooke's Law and bar extensions [5, Sect 5.2, 5.3, 5.4]
- Internal states of stress [5, Sect 5.5]

Displacement Diagrams

- Procedure for drawing displacement diagrams [5, Sect 2.3]
- Displacement diagram used for analysing real structures
- Interpreting displacement diagrams

Virtual work

- Real work
- Derivation of virtual work for pin-jointed frames
- Using virtual work to find extensions or nodal displacements
- Using virtual work to find forces or bar tensions

Structural design

- Iterative design
- Structural optimisation

4. Equilibrium of Beams (2L)

- Introduction, hypotheses, sign conventions *(5) Sect. 3.1, 3.2*
- Distortion produced by internal forces
- Calculation of M, S, and T by analysis of free bodies *(5) Sect. 3.2-3.4*
- Differential relationships between q, S, and M *(5) Sect. 3.5*
- Construction of bending moment diagrams
- Statical indeterminacy
- Case study

5. Deflection of Straight Elastic Beams (2L)

- Curvature and change of curvature, integration of curvature to find deflection *(5) Sect. 8.1,8.2*
- Deflection of elastic beams by integration *(5) Sect. 8.3*
- Deflection of elastic beams by superposition of deflection coefficients *(5) Sect. 8.4*

6. Stresses in Elastic Beams (5L)

- Introduction, basic geometric concepts *(5) Sect. 7.2*
- Bending of beams with rectangular cross-section *(5) Sect. 7.5*
- Bending of beams with non-rectangular cross-section, centroid and second-moment of area
- Use of section tables
- Combined bending moment and axial force
- Bending stresses in composite beams, transformed section, bending of reinforced concrete beams
- Shear stresses in beams *(5) Sect. 7.6*

7. Buckling of Columns (3L)

- Introduction, examples, hypotheses
- Euler column, fixed-end conditions, effective length *(5) Sect. 9.4 (6) Sect 5.1*
- Critical stress
- Imperfections *(6) Sect 5.2*
- Design of columns

REFERENCES

(1) GORDON, J.E. STRUCTURES OR WHY THINGS DON'T FALL DOWN
(2) HEYMAN, J. THE SCIENCE OF STRUCTURAL ENGINEERING
(3) MERIAM,J.L. & KRAIGE,L.G. ENGINEERING MECHANICS.VOL.1:STATICS
(4) FRENCH, M. INVENTION AND EVOLUTION
(5) CRANDALL,S.H.DAHL,N.C. & LARDNER,T.J INTRODUCTION TO THE MECHANICS OF SOLIDS,with SI Units
(6) HEYMAN,J.BASIC STRUCTURAL THEORY
(7) HEYMAN, J. STRUCTURAL ANALYSIS: A HISTORICAL APPROACH

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 [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] 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.

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.

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.

Last modified: 30/07/2024 08:43

Source URL (modified on 30-07-24): https://teaching.eng.cam.ac.uk/content/engineering-tripos-part-ia-1p2-structures-2024-25

Links
[1] mailto:jma42@cam.ac.uk
[2] mailto:fam20@cam.ac.uk
[3] https://teaching.eng.cam.ac.uk/content/form-conduct-examinations
[4] https://teaching.eng.cam.ac.uk/content/uk-spec