# UNIVERSITY OF LONDON

## B.Sc. (ENGINEERING) EXAMINATION 1963

### PART II

**for Internal and External Students**

## (11) STRENGTH OF MATERIALS

Thursday, 13 June: 10 to 1

*Answer SIX questions, not more than four from either section. Answers to questions 1 to 6 to be written in an answer-book marked A and answers to questions 7 to 11 to be written in an answer-book marked B.*

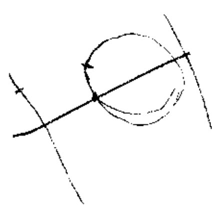
### Section A

1. A horizontal steel beam ABCDE is of uniform section and is 27 ft long. AB = 4 ft, BC = 12 ft, CD = 8 ft and DE = 3 ft. The beam rests on supports at B and D 20 ft apart; it carries a load of 5 tonf at C and in addition an anticlockwise couple of 20 tonf ft is applied at the left hand end A.
   (*a*) Sketch the bending moment diagram for the beam showing the principal values on the diagram.
   (*b*) Determine the deflection at each end of the beam, stating in each case whether the deflection is up or down. $E = 13\,000$ tonf/in$^2$, $I = 145{\cdot}7$ in$^4$.

2. A 2-in diameter shaft is made of a material which in a direct-tension test gave elastic failure at 22 tonf/in$^2$. Poisson's ratio for the material is 0·3.
   Estimate the torque which will just cause elastic failure in the shaft when the torque is applied in addition to a bending moment of 30 000 lbf in taking as the criterion of failure
   (*i*) the maximum principal stress,
   (*ii*) the maximum total strain energy.
   Principal stress and strain energy formulae may be used without derivation; equivalent bending moment formulae may be used but they should be derived.



**Turn over**



3. Derive the relationships between the following elastic constants
   (*a*) $E$, $G$ and $\nu$, and
   (*b*) $E$, $K$ and $\nu$,
   and hence express $K$ in terms of $E$ and $G$.
   $E$, $G$, $K$ and $\nu$ have their usual meanings.
   In an experiment to determine $E$ and $G$ for steel, round test pieces nominally $\frac{1}{2}$ in diameter were subjected to pure tension and pure torsion tests. If the actual diameters were 0·496 in but in the calculations 0·500 in was used, determine the percentage error in the value of $\nu$ obtained, assuming the correct values for $E$ and $G$ to be, $E = 13\ 500$ tonf/in$^2$ and $G = 5\ 250$ tonf/in$^2$.

4. A bar of uniform flexural rigidity $EI$ and total effective length $6a$ is bent to the shape shown in Figure 1 with end D firmly fixed; AB and CD are horizontal and BC is vertical. A load $W$ is suspended from the free end A.
   Derive expressions for the vertical deflections due to bending at A and C in terms of $W$, $a$ and $EI$.

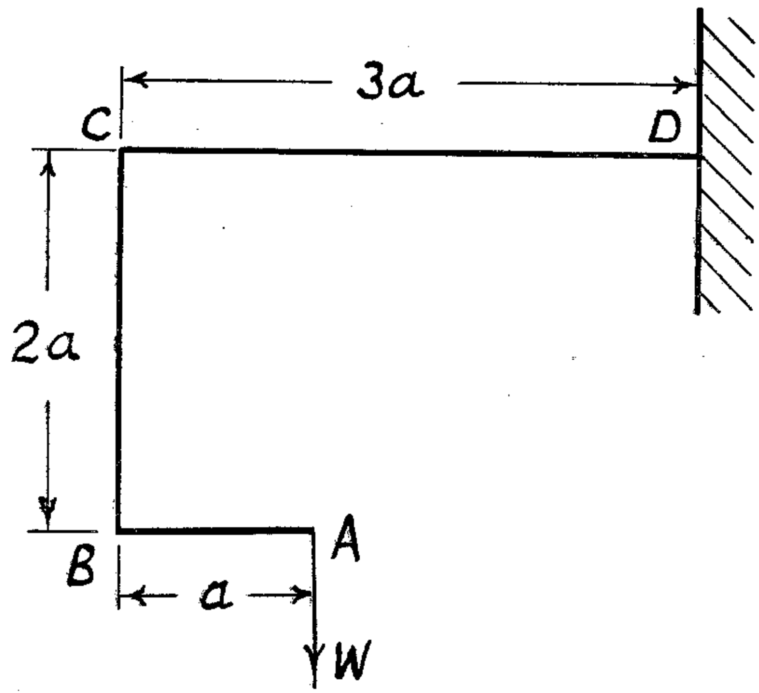
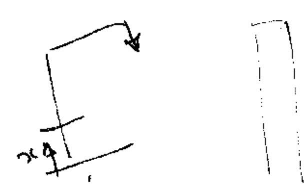



*Figure* 1

5. (*a*) Describe the term 'core of the section' and discuss its importance.
   (*b*) A rectangular section of size $b \times h$ is subjected to a direct compressive load. Show that when the eccentricity of loading is $b/6$ or $h/6$ along the relevant axis of symmetry, the stress at the extreme outer fibres on the other side of the axis is zero.
   Give a sketch of the core of this section explaining how it is arrived at.
   (*c*) A 12 in × 8 in rolled steel I section column has a cross-sectional area 19·12 in$^2$ and the values of its second moments of area are $I_{xx} = 487{\cdot}8$ in$^4$ and $I_{yy} = 65{\cdot}18$ in$^4$. Make a sketch of the section showing also with dimensions the core of the section.

$\sigma = \frac{P}{A} \pm \frac{Pey}{I}$



6. A steel beam ABCD of uniform section is firmly built-in at the ends A and D and propped at the mid-span point B so that at B the beam is level with the ends A andD. The effective span is AD = 24 ft; AB = 12 ft, BC = 3 ft and CD = 9 ft. The beam carries a point load of 8 tonf at C. Determine the bending moments and reactions at A, B and D and the bending moment at C. Sketch the bending moment diagram for the beam showing on it the calculated values.

## Section B

*Use a separate answer-book and write 'Section B' on the cover.*

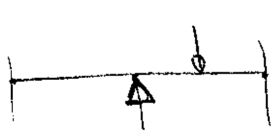
7. (*a*) Describe briefly, with the aid of sketches, the atomic arrangement in the crystal planes and directions in which slip most commonly occurs, in crystals of metals having close-packed types of structure.
(*b*) Describe briefly how the orientation of a close-packed hexagonal single crystal influences the value of the applied stress required to cause slip, when the crystal is stressed in tension.
(*c*) State what effect solute atoms in the crystal lattice have on the stress required to cause slip.
(*d*) Indicate how the process of slip in polycrystalline samples of metals is affected by the grain boundaries.

8. Two metals A and B when alloyed show partial solid solubility in one another, forming solid solutions $\alpha$ and $\beta$ respectively. These are the only solid phases in the system.
The following table gives values for the maximum solid solubility under equilibrium conditions.

| Temperature °C | Maximum solubility, weight per cent | |
|---|---|---|
| | B in A $\alpha$ | A in B $\beta$ |
| 200 | 10 | 2 |
| 400 | 20 | 3 |
| 600 | 32 | 5 |
| 800 | 50 | 10 |
| 900 | 40 | 5 |

Using these values draw on squared paper a possible phase diagram for the whole system, labelling all regions shown.
An alloy containing 30 per cent B is slowly cooled from 800°C to room temperature. Assuming that equilibrium is attained at 800°C and maintained during cooling, calculate the percentage of $\beta$ phase present at 400°C.
State what heat treatments might be applied to produce the following structures at room temperature in this alloy:
(*a*) a structure consisting entirely of $\alpha$ solid solution, and
(*b*) a structure consisting of very small crystals of $\beta$ phase dispersed in a matrix of $\alpha$ phase.

**Turn over**



9. Describe *briefly* the essential features of the following:
   (*a*) interstitial and substitutional solid solutions,
   (*b*) eutectic and eutectoid reactions,
   (*c*) a tensile fracture and a fatigue fracture of a ductile metal.

10. Sketch
   (*a*) a typical stress-strain curve for a specimen of annealed mild steel tested in tension to fracture,
   (*b*) a typical stress-strain curve for a specimen of the same steel in the cold-worked condition, and
   (*c*) a typical 'S-N' fatigue curve for the same steel in the annealed condition.
   (*Note*—actual values of stress etc. need not be given.)
   By reference to the appropriate curves, describe what is meant by (*i*) the yield point, (*ii*) the percentage elongation and (*iii*) the fatigue limit of the steel, and discuss briefly the significance of these properties to the engineer.

11. Re-write the following paragraphs correcting the errors:
   A copper–zinc alloy containing 30 per cent of zinc is generally used in the as-cast condition. The alloy solidifies over a wide range of temperature, and when chill cast shows marked coring and contains a considerable proportion of the beta phase. If the cast alloy is annealed for a few hours at 300°C, a structure consisting of homogeneous alpha is obtained. Cold-working of an annealed alloy causes work-hardening, leading to an increase in the strength and ductility of the material. If a heavily cold-worked sample of the alloy is annealed for an hour at 600°C, it recrystallizes completely to form a fine-grained structure containing numerous mechanical twins. This has little effect on the mechanical properties of the alloy, but it reduces appreciably the internal stresses in the cold-worked material. Hot-working is seldom used for this alloy since it leaves it in a condition particularly prone to season cracking, which is a type of stress-corrosion failure characterized by transcrystalline fracture.
   The 60/40 type of brass is essentially a hot-working alloy and is not used in the as-cast condition. Hot-working is used in preference to cold-working because of the superior surface finish and dimensional accuracy that can be achieved. The alloy solidifies as a mixture of the alpha and beta phases, predominantly alpha, but more beta is formed during cooling to room temperature.

M. S. FISHER
H. C. OLIVER
D. R. F. WEST
J. M. ZAREK