National Exams December 2014

07-Mec-B9 ADVANCED ENGINEERING STRUCTURES

3 Hours Duration

NOTES:

1. If doubts exist as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

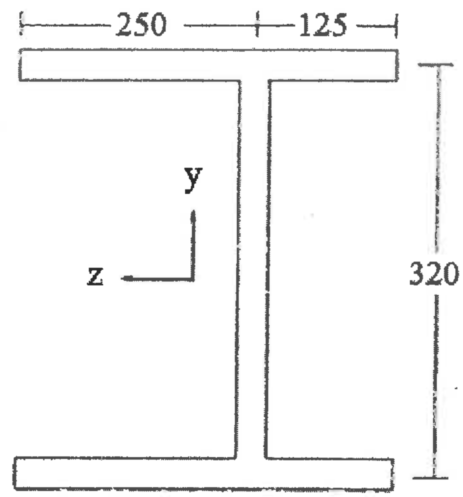
2. Any non-communicating calculator is permitted. This is an open book exam.

3. Any FIVE (5) questions constitute a complete exam paper. If more than five questions are attempted, only the first five as they appear in the answer book will be marked.

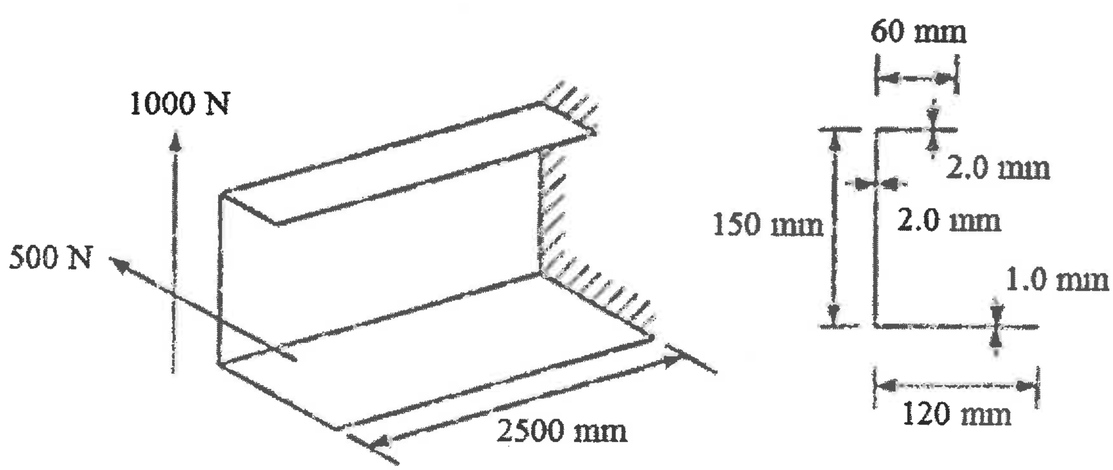
4. All problems are of equal total value. Marks for individual questions are indicated within each problem.

1. The thin-walled open section shown below (symmetric about the z-axis, dimensions shown are in mm), is subjected to an upward vertical force of 25 KN acting through the shear center.

a) Find the shear flow distribution in the thin walls of the section. All of the walls have the same thickness of 3 mm. All dimensions are to the mid-planes of the walls. (10 marks)
b) Locate the shear center relative to the vertical web. (5 marks)
c) Calculate the maximum shear stress in the section if the shear force acts through the vertical web instead of through the shear center. (5 marks)



2. A thin-walled, cantilever beam supports two loads at its free end as shown below. Calculate the maximum bending and shear stresses at a section 500 mm away from the rigid support section. Assume the applied loads are acting at the shear center of the cross-section. (20 marks)



3. The following data points have been obtained from a series of mechanical strain cycling tests on an aircraft component:

Range of plastic strain $\Delta\varepsilon$	Number of cycles to failure N
0.0400	120
0.0211	800
0.0160	1900
0.0084	8000

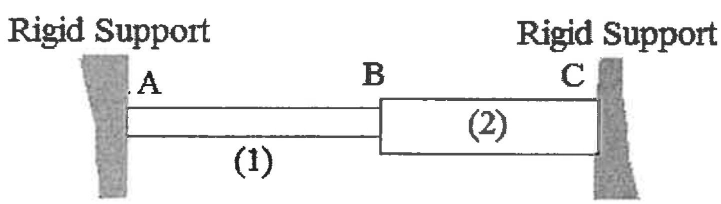
a) Show that these results can be represented by an equation of the type: $\Delta\varepsilon = CN^{\alpha}$ where C and α are material constants. (10 marks)

b) A component made from this material is subjected to a range of plastic strain of 0.015 for the first 500 cycles and then to a range of plastic strain of 0.01 for the rest of its service life. Calculate the total number of cycles before failure, assuming the material obeys Miner's cumulative damage law. (10 marks)

4. Two uniform linearly elastic rods are welded together at B, and the resulting two-segment rod is attached to rigid supports at A and C. Rod (1) has a modulus $E_1 = 165$ GPa, cross-sectional area $A_1 = 10$ cm^2, length $L_1 = 165$ cm, and coefficient of thermal expansion $\alpha_1 = 13 \times 10^{-6}$/°C. Rod (2) has a modulus $E_2 = 90$ GPa, cross-sectional area $A_2 = 15$ cm^2, length $L_2 = 110$ cm, and coefficient of thermal expansion $\alpha_2 = 25 \times 10^{-6}$/°C.

a) Determine the axial stresses in the rods if their temperature is raised by 70 °C. (15 marks)

b) Determine the displacement magnitude and direction for joint B (5 marks)



5. A cantilevered structural beam of solid square cross-section (**w** by **w**) is subjected at its free end to a compressive axial force of magnitude P = 178 kN and a torque T = 17 kN.m. This bar is to be designed in accordance with the maximum-shear-stress criterion of failure, with a safety factor of 4.

a) What is the minimum allowable dimension **w** if $\sigma_{yielding} = 325$ MPa? (10 marks)

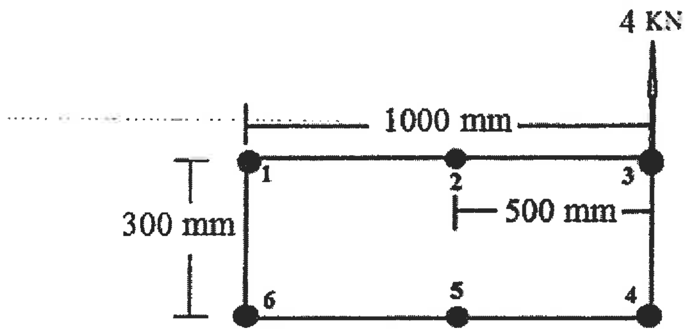
b) What would your answer be if the Von-Mises stress criterion is used? (10 marks)

6. An aircraft wing skin panel which can be modeled as a semi-infinite plate, has a 1 mm edge crack and is subjected to typical cyclic service loads. The component of those loads that act to propagate the crack can be simplified to constant amplitude stress loading of 100 N/mm^2 normal to the crack. If the panel is made from a metal alloy with fracture toughness of 3000 N/mm$^{3/2}$ and a crack growth rate of $35\times10^{-15}(\Delta K)^4$ mm/cycle, determine the maintenance interval required to detect the crack before it grows to half its critical length. (20 marks)

7. The stiffened thin walled wing box shown below has a wall thickness t = 1 mm and has been idealized into normal stress carrying booms 1 to 6 and shear only resisting thin wall panels. The box is subjected to a vertical force of 4,000 N acting upward as shown below. The boom areas are: $B_1 = B_6 = 600\ mm^2$, $B_2 = B_5 = 400\ mm^2$ and $B_3 = B_4 = 900\ mm^2$.

a) Determine the location of the shear center with respect to boom 6 (10 marks)

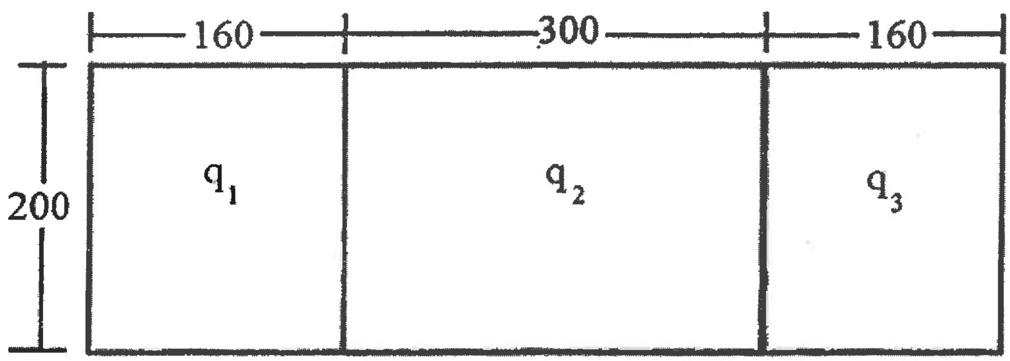
b) Determine the shear flow in the panels of the idealized box. (10 marks)



8. The figure below shows a three cell thin wall wing box made from a material whose shear modulus G is 15 GPa and subjected to a constant clockwise torque of 10,000 N.m. The upper panels of the box have a constant thickness of 2 mm, while the lower panels have a thickness of 1.5 mm. All vertical panels are 1 mm in thickness.

a) Determine the shear flows q_1, q_2 and q_3 in the three cells (15 marks)

b) Determine the magnitude and location of the maximum shear stress. (5 marks)



All dimensions shown are in mm.