National Exams May 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.

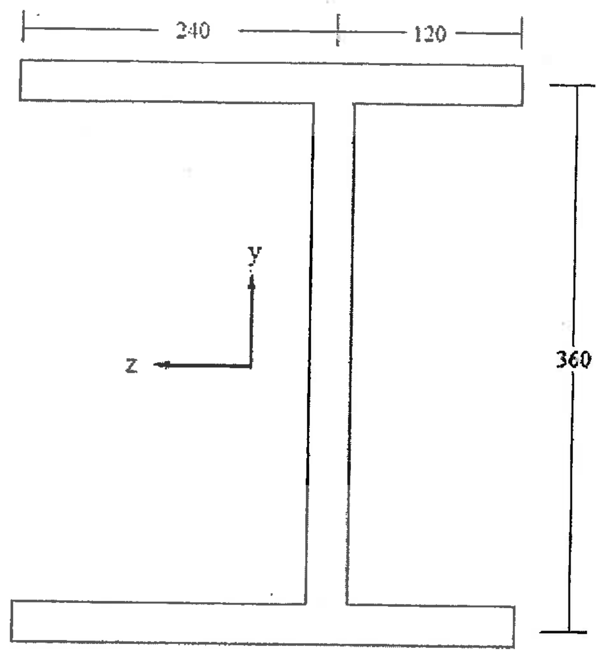
4. All problems are of equal total value. Marks for individual questions are indicated within each problem.

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 15 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- An aircraft wing skin panel which can be modeled as a semi-infinite plate, has an edge crack of length 0.22 mm 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 160 N/mm^2 normal to the crack. If the panel is made from a metal alloy with fracture toughness of 2900 $N/mm^{3/2}$ and a crack growth rate of $32\times10^{-15}(\Delta K)^4$ mm/cycle, determine the maintenance interval required to detect the crack before it grows to half its critical length. (20 marks)

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
0.0380	250
0.0221	900
0.0150	2200
0.0080	12000

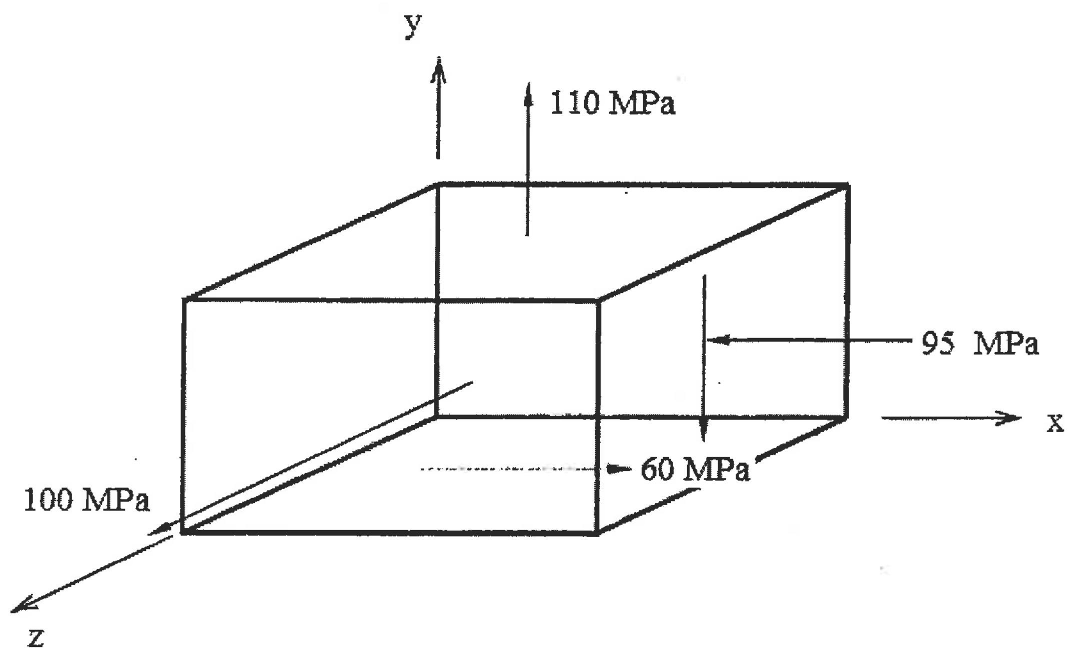
a) Determine the coefficient C and exponent α that would best represent these results through an equation of the type: $\Delta\varepsilon = CN^{\alpha}$. (10 marks)

b) A component made from this material is subjected to a range of plastic strain of 0.018 for the first 300 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- An isotropic ductile solid with a yielding strength of 170 MPa is subjected to the state of stress shown below. Predict whether such stresses will cause failure according to the:

a) maximum shear stress criterion (10 marks)

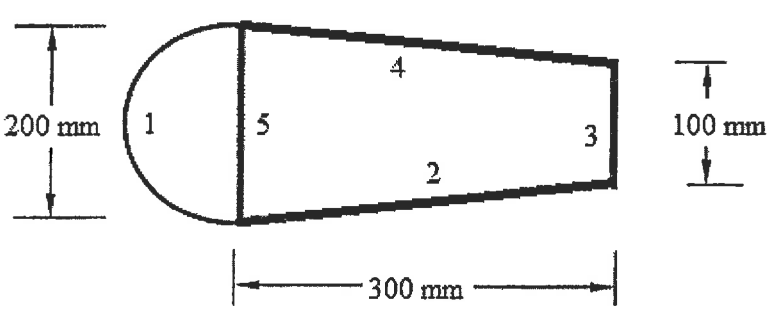
b) Von-Mises failure criterion (10 marks)



5- The torsion box shown below is symmetric with respect to the horizontal and is subjected to a constant torque $T = 38000$ N.m. acting clockwise.

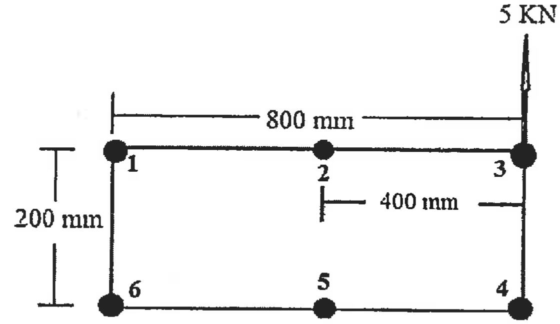
a) Calculate the shear flow q in walls 1, 2, 3, 4 and 5. The thickness of each wall is as follows: $t_1 = 1$ mm, $t_2 = 1.5$ mm, $t_3 = 3$ mm, $t_4 = 2$ mm and $t_5 = 4$ mm. <u>Wall 1 is semi-circular</u>. (15 marks)

b) What is the maximum shear stress and in which wall does it occur? (5 marks)



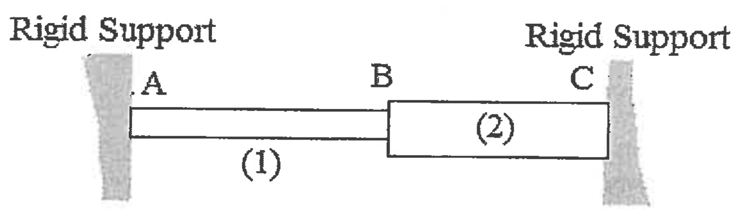
6- A stiffened thin walled wing box has a wall thickness $t = 2$ mm and has been idealized into normal stress carrying booms 1 to 6 and shear only resisting thin wall panels. The box is subjected to a vertical force of 5,000 N acting upward as shown below. The boom areas are: $B_1 = B_6 = 500\ mm^2$, $B_2 = B_5 = 300\ mm^2$ and $B_3 = B_4 = 800\ mm^2$.

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)



7- 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 $E_1 = 160$ GPa, cross-sectional area $A_1 = 12\ cm^2$, length $L_1 = 150$ cm, and coefficient of thermal expansion $\alpha_1 = 10 \times 10^{-6}/°C$. Rod (2) has a modulus $E_2 = 110$ GPa, cross-sectional area $A_2 = 25\ cm^2$, length $L_2 = 100$ cm, and coefficient of thermal expansion $\alpha_2 = 19 \times 10^{-6}/°C$.

a) Determine the axial stresses in the rods if their temperature is raised by 65 °C. (15 marks)
b) Determine whether joint B moves to the right or left and by how much? (5 marks)



8- The horizontally symmetric, constant wall thickness (1 mm) thin walled wing box shown below is idealized by the assumption that all direct stresses are resisted by the four booms while the thin walls are only effective in resisting shear. The leading edge (wall 2-3) of the box is semi elliptical with a major radius being twice the minor radius. Booms 1 and 4 have areas equal to $500\ mm^2$ and booms 2 and 3 equal to $400\ mm^2$.

a) Determine the location of the shear center of the box (10marks)
b) Determine the shear flow around the box if an upward shear force of 10,000 N is acting 100 mm to the left of the shear center. (10 marks)