National Exams December 2015

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.

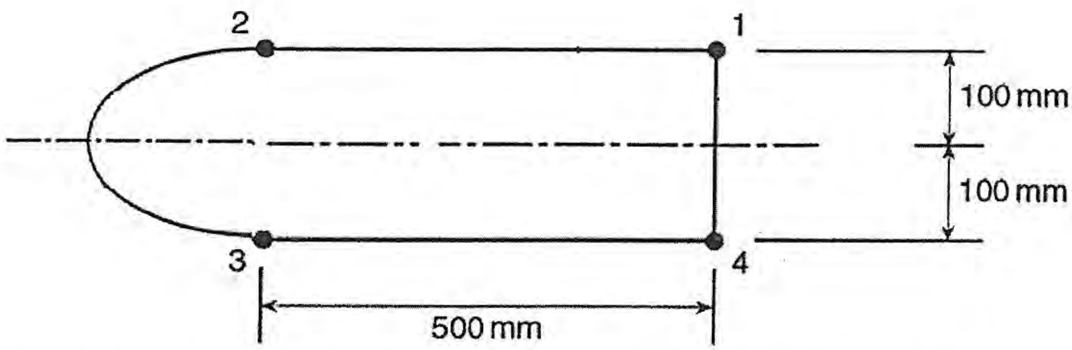
3. Any FIVE (5) questions constitute a complete exam paper. If more than five questions are attempted, only the first five as they appear in the answer book will be marked.

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

1. An aircraft wing skin panel which can be modeled as a semi-infinite plate, has an edge crack of length 0.3 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 208 N/mm^2 normal to the crack. If the panel is made from a metal alloy with fracture toughness of 2100 $N/mm^{3/2}$ and a crack growth rate of $37\times10^{-15}(\Delta K)^4$ mm/cycle, determine maintenance interval in cycles required to detect the crack before it grows to half the critical length that leads to panel fracture. (20 marks)

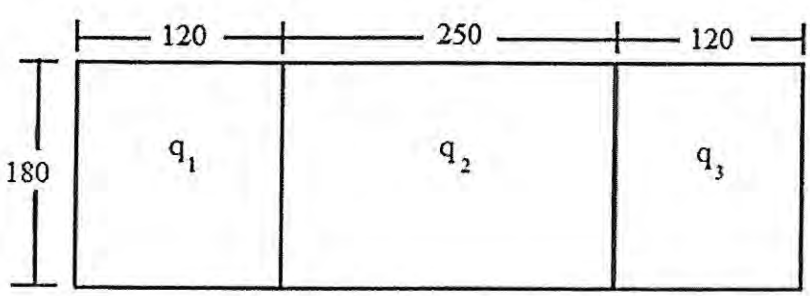
2. The horizontally symmetric, constant wall thickness (1.5 mm) thin walled idealized wing box shown below is subjected to a vertical shear force of 12,000 N acting upward. Assume wall 2-3 to be semicircular and take areas for booms 1 and 4 to be equal to 550 mm^2 and booms 2 and 3 to be equal to 500 mm^2. Also, assume the thin walls to be only effective in shear.

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



3. The figure below shows a three cell thin wall wing box made from a material whose shear modulus G is 12 GPa and subjected to a constant clockwise torque of 12,000 N.m. The upper panels of the box have a thickness of 2.5 mm, while the lower panels have a thickness of 2.0 mm and the vertical panels are 1.5 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)



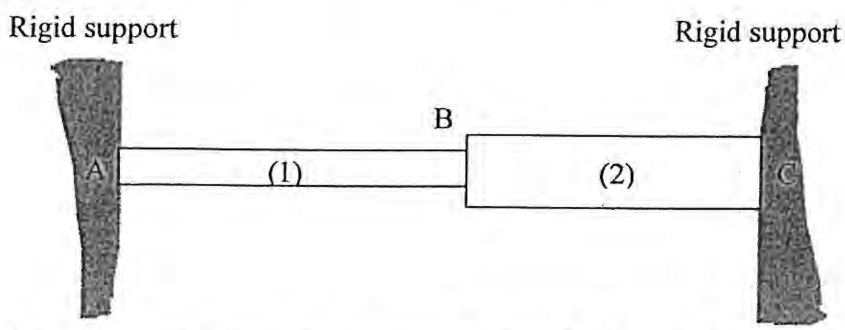
All dimensions shown are in mm.

4. 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 $P = 225 \times 10^3$ N and a torque $T = 23 \times 10^3$ N.m. This bar is to be designed in accordance with the maximum-shear-stress criterion of failure, with a safety factor of 4.

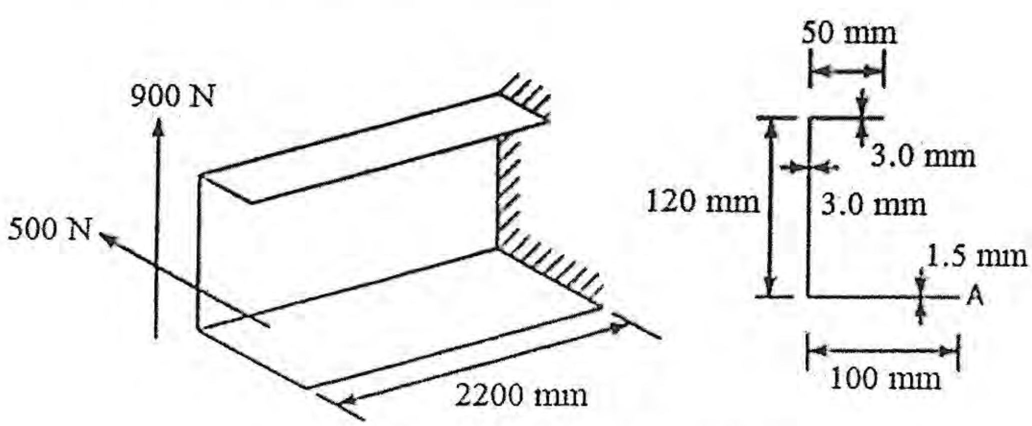
a. What is the minimum allowable dimension **w** if $\sigma_{yielding} = 320$ MPa? (10 marks)
b. What would your answer be if the Von-Mises stress criterion is used? (10 marks)

5. The two uniform linearly elastic rods shown below 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 $E_1 = 110$ GPa, cross-sectional area $A_1 = 2200$ mm^2, length $L_1 = 1600$ mm, and coefficient of thermal expansion $\alpha_1 = 6\text{x}10^{-6}/°C$. Rod (2) has a modulus $E_2 = 75{,}000$ GPa, cross-sectional area $A_2 = 2600$ mm^2, length $L_2 = 1100$ mm, and coefficient of thermal expansion $\alpha_2 = 8\text{x}10^{-6}/°C$.

a. Determine the axial stresses in the rods if the temperature is raised by 50 °C. (10 marks)
b. Determine whether joint B moves to the right or left and by how much? (10 marks)



6. A thin-walled, cantilever beam supports two loads at its free end as shown below. Calculate the bending stress at the extremity of the lower flange (point A) at a section 1300 mm away from where the loads are applied. Assume the applied loads are acting at the shear center of the section. (20 marks)



7. An isotropic ductile solid with a yielding strength of 325 MPa is subjected to x-y-z state of normal stresses equal to -100 MPa, 200 MPa and 290 MPa, respectively, plus a shear stress in the x-y plane equal to 90 MPa. Predict whether such stresses will cause failure according to the:

a. maximum shear stress criterion (10 marks)

b. Von-Mises criterion. (10 marks)

8. The thin-walled open structural element shown below (symmetric about the z-axis), is subjected to a downward vertical force of 16 KN acting through the shear center. All the dimensions shown below are in mm and are to the mid-planes of the walls and all of the walls have the same thickness of 2.0 mm. .

   a. Find the shear flow distribution in the thin walls of the section. (10 marks)
   b. Locate the shear centre with respect 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 the shear center. (5 marks)