National Exams May 2018

16-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.

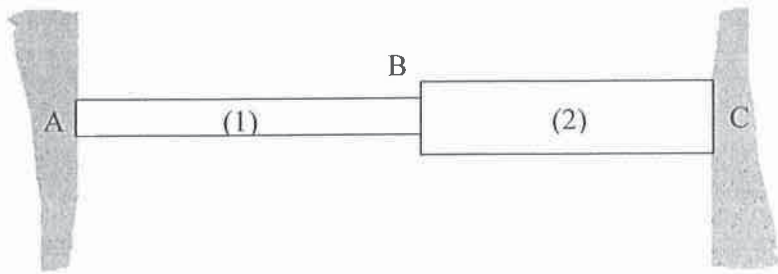
2. Any non-communicating calculator is permitted. This is an open book exam.

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 of 20 marks each. Marks for individual questions are indicated within each problem.

1. 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 = 150 GPa, cross-sectional area A_1 = 2000 mm^2, length L_1 = 1800 mm, and coefficient of thermal expansion α_1 = 8x10^{-6}/°C. Rod (2) has a modulus E_2 = 95,000 GPa, cross-sectional area A_2 = 2600 mm^2, length L_2 = 1000 mm, and coefficient of thermal expansion α_2 =9x10^{-6} /°C.

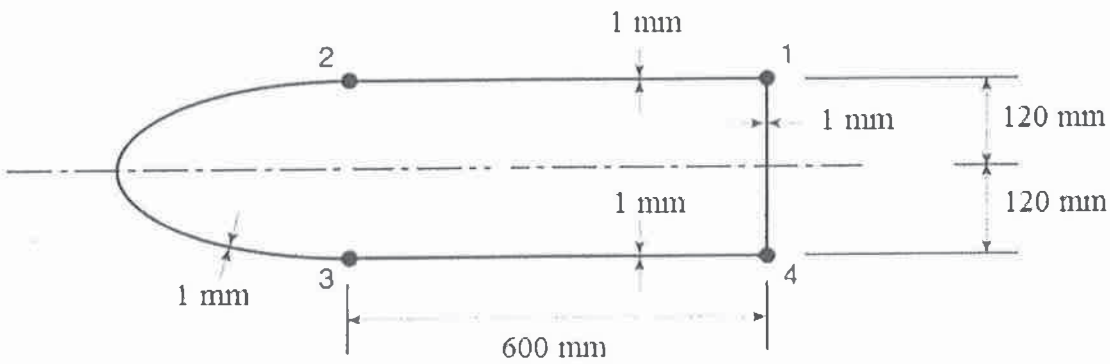
a. Determine the axial stresses in the rods if the temperature is raised by 60 °C. (10 marks)
b. Determine whether joint B moves to the right or left and by how much? (10 marks)



2. An aircraft wing skin panel which can be modeled as a semi-infinite plate, has an edge crack of length 0.55 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 200 N/mm^2 normal to the crack. If the panel is made from a metal alloy with fracture toughness of 2700 N/mm$^{3/2}$ and a crack growth rate of $31\times10^{-15}(\Delta K)^4$ mm/cycle, determine the maintenance interval required to detect the crack before it grows to half its critical length. (20 marks)

3. The horizontally symmetric, constant wall thickness (1 mm) thin walled idealized wing box shown below is subjected to a vertical force of 10,000 N acting upward. Assume the leading edge wall 2-3 to be semicircular and take areas for booms 1 and 4 to be equal to 500 mm^2 and booms 2 and 3 to be equal to 400 mm^2. Finally, assume the thin walls to be effective only 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 force is acting 100 mm to the left of the shear center. (10 marks)



4. 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
0.0500	150
0.0211	1100
0.0160	2200
0.0084	12000

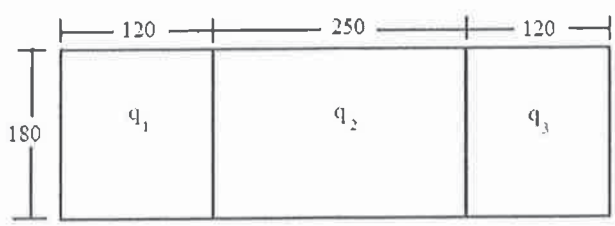
a. Determine the coefficient C and exponent α of an equation of the type: $\Delta\varepsilon = CN^{\alpha}$ that is proposed to represent the above data. (10 marks)

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 0.009 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)

5. The figure below shows a three cell thin wall 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 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)

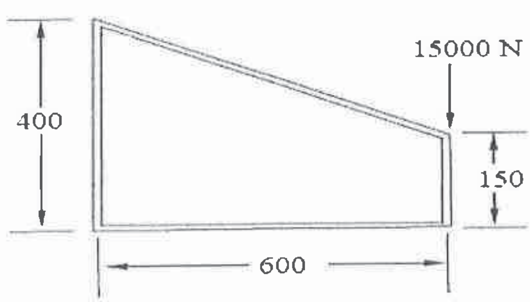


All dimensions shown are in mm.

6. The closed thin wall beam with the cross section shown below (all dimensions are median distances in mm) and a wall thickness of 2 mm is subjected to the vertical force shown. If the walls are effective in bending as well as in shear, determine:

   a. The shear flow around the section (10 marks)

   b. The bending stresses at the 4 corners of a section on the beam located 500 mm behind the one shown (10 marks)



7. An isotropic ductile solid with a yielding strength of 315 MPa is subjected to x-y-z state of normal stresses equal to -110 MPa, 220 MPa and 250 MPa, respectively, plus a shear stress in the x-y plane equal to 80 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 20 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 2.5 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)