National Exams May 2011

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.

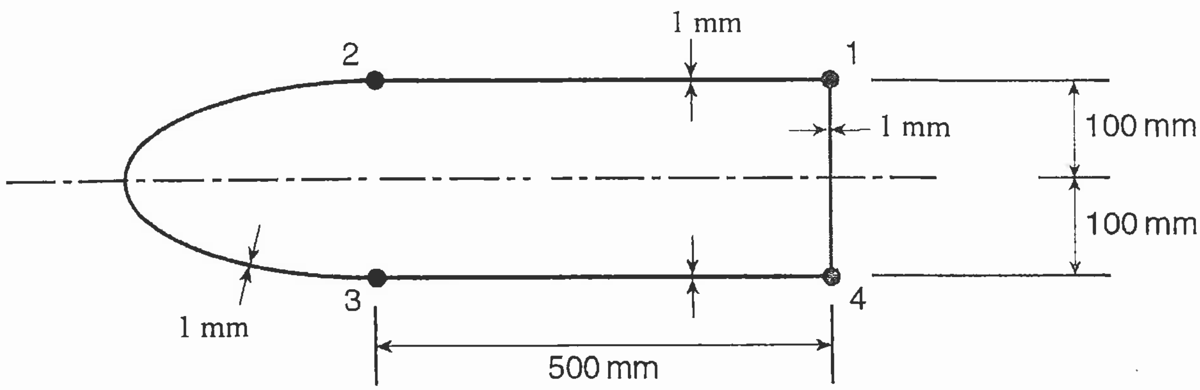
2. Any non-communicating calculator is permitted. This is an open book exam.

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 horizontally symmetric, constant wall thickness (1 mm) thin walled idealized wing box shown below is subjected to a vertical shear force of 10,000 N acting upward. Assume 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 only effective in shear.

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



2. 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 220 N/mm^2 normal to the crack. If the panel is made from a metal alloy with fracture toughness of 2000 $N/mm^{3/2}$ and a crack growth rate of $38 \times 10^{-15}(\Delta K)^4$ mm/cycle, determine if a maintenance interval equivalent to 10,000 cycles is adequate to detect the crack before it grows to a critical length leading to panel fracture. (20 marks)

3. 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 = 250 x 10^3 N and a torque T = 20 x 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 3.

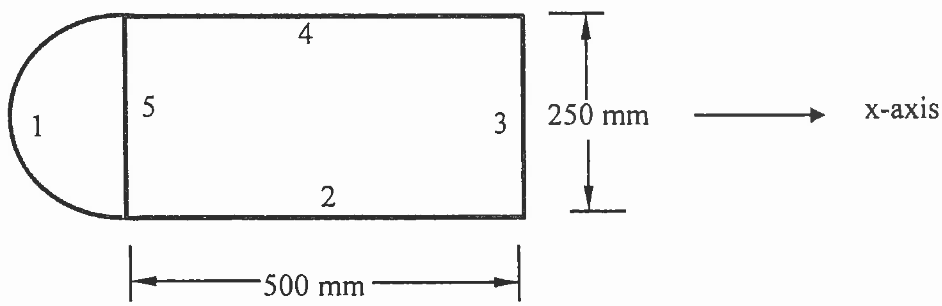
a. What is the minimum allowable dimension **w** if $\sigma_{yielding}$ = 300 MPa? (10 marks)
b. What would your answer be if the Von-Mises stress criterion is used? (10 marks)

4. The wing torsion box shown below is symmetric with respect to the x-axis and is subjected to a constant torque T = 35000 N.m acting clockwise.

a. Calculate the maximum shear stress in the section. The thickness of each wall is as follows: t_1 = 3 mm, t_2 = 2 mm, t_3 = 4 mm, t_4 = 3 mm and t_5 = 1 mm. Wall 1 is semi-circular. (15 marks)

b. Assuming a two dimensional flow situation, estimate the torsional divergence speed for the wing if: (5 marks)

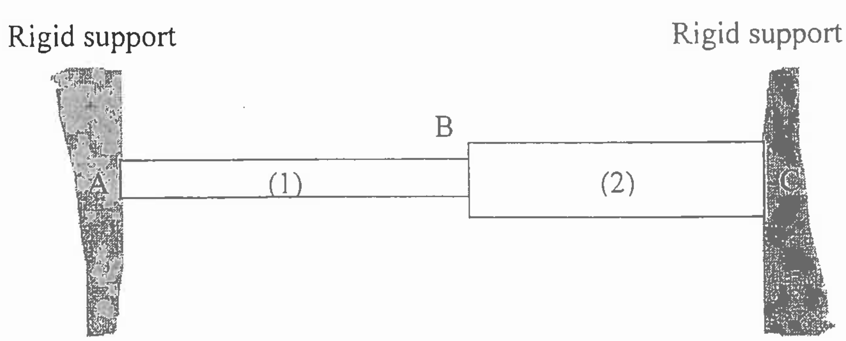
Total wing surface area S = 25 m^2
Wing lift curve slope = 4.35/rad
Material's shear modulus G = 40 GPa
Distance from flexural center to aerodynamic center = 250 mm.



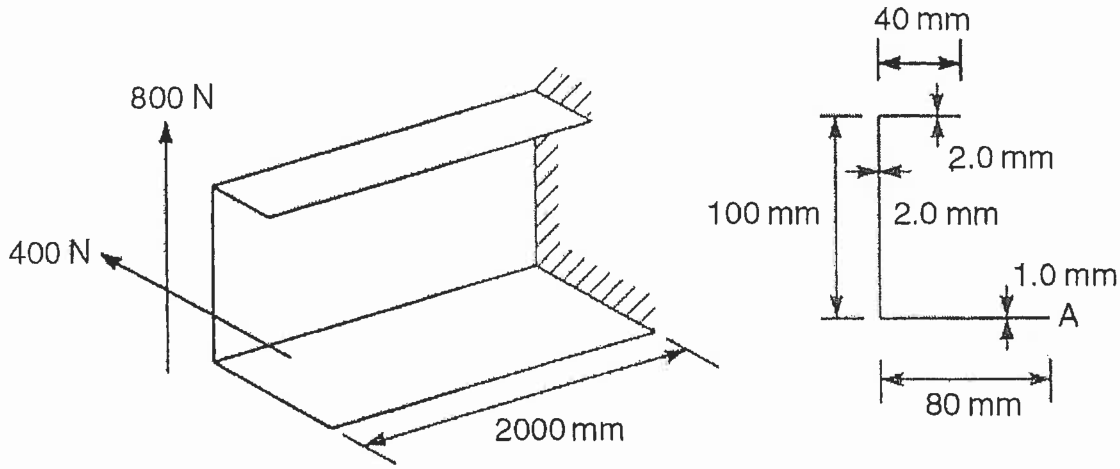
ALL DIMENSIONS SHOWN ARE MEDIAN DISTANCES

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 = 100 GPa, cross-sectional area A_1 = 2000 mm^2, length L_1 = 1500 mm, and coefficient of thermal expansion $\alpha_1 = 5 \times 10^{-6}/°C$. Rod (2) has a modulus E_2 = 70,000 GPa, cross-sectional area A_2 = 2500 mm^2, length L_2 = 1000 mm, and coefficient of thermal expansion $\alpha_2 = 9 \times 10^{-6}/°C$.

a. Determine the axial stresses in the rods if the temperature is raised by 40 °C. (10 marks)
b. Determine whether joint B moves to the right or left and by how much? (10 marks)



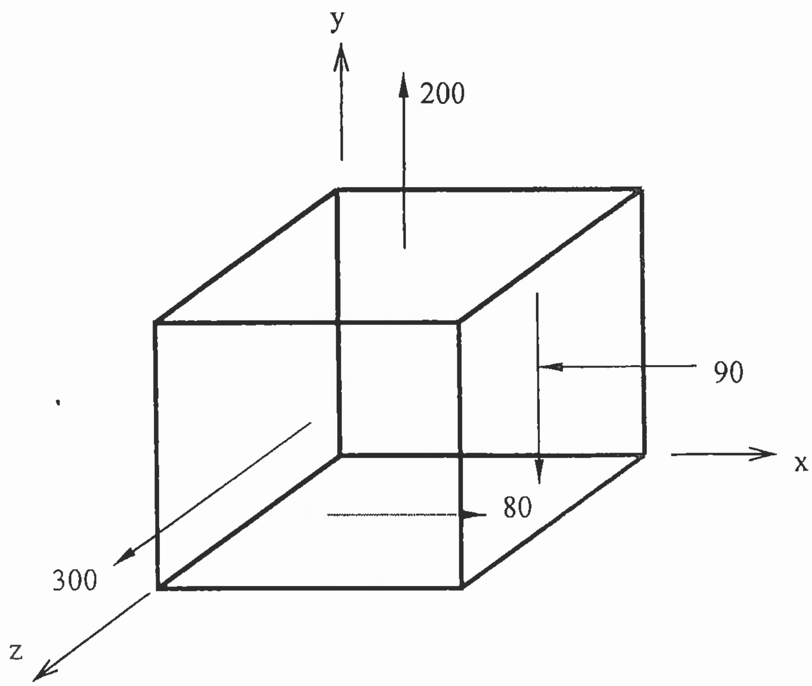
6. A thin-walled, cantilever beam supports two loads at its free end as shown below. Calculate the bending stress at the extremity of the lower flange (point A) at a section 1500 mm away from where the loads are applied. Assume the applied loads are acting at the shear center of the section. (20 marks)



7. An isotropic ductile solid with a yielding strength of 325 MPa is subjected to x-y-z state of stress depicted below (in MPa). Predict whether such stresses will cause failure according to the:

a. maximum shear stress theory (10 marks)

b. energy of distortion theory. (10 marks)



8. The thin-walled open structural element shown below (symmetric about the z-axis), is subjected to an upward vertical force of 22 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 2.5 mm. All the dimensions are in mm and are to the mid-planes of the walls. (15 marks)
   b. 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)