National Exams May 2017

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. Marks for individual questions are indicated within each problem.

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

Range of plastic strain $\Delta\varepsilon$	Number of cycles to failure N
0.0380	240
0.0218	870
0.0120	3900
0.0070	14000

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 0.011 for the first 500 cycles, then to a range of plastic strain of 0.02 for the next 300 cycles and finally to a range of plastic strain of 0.009 for rest of its service life. Calculate the total number of cycles before failure, assuming the material obeys Miner's cumulative damage law. (10 marks)

2. An isotropic metallic alloy with a yielding strength of 360 MPa is subjected to the 3D state of stresses shown below. Will such stresses cause yielding according to the:

a. Maximum shear stress criterion (10 marks)
b. Von-Mises criterion (10 marks)
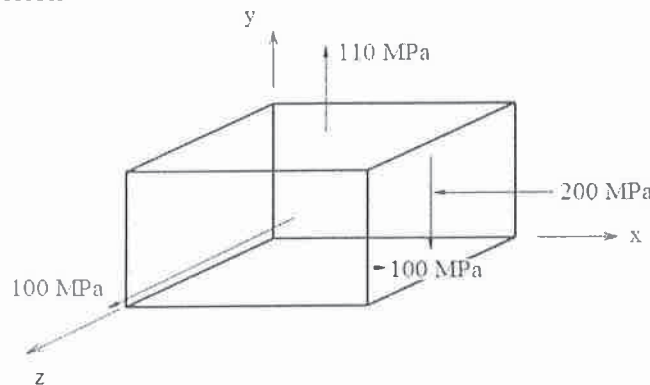
3. An orthotropic composite material system has the following lamina properties:

$$E_{11} = 205 \text{ GPa}$$
$$E_{22} = 25 \text{ GPa}$$
$$G_{12} = 15 \text{ GPa}$$
$$\nu_{12} = 0.28$$

a) Determine the various entries in the 0° lamina stiffness matrix [C]. (5 marks)
b) Evaluate the transform stiffness matrix [Q] for a 30° ply. (5 marks)
c) Evaluate the transform stiffness matrix [Q] for a 75° ply. (5 marks)
d) Determine σ_x, σ_y, and τ_{xy} for a 90° ply if ε_x, ε_y, γ_{xy} are given by 0.006, 0.004 and -0.0005 respectively (5 marks)

4. A cantilevered structural beam of solid square cross-section (**w** by **w**) is subjected at its free end to a compressive axial force P equal in magnitude to 265×10^3 N and a torque T equal in magnitude to 28×10^3 N.m. This bar is to be designed in accordance with the maximum-shear-stress criterion of failure, with a safety factor of 1.5.
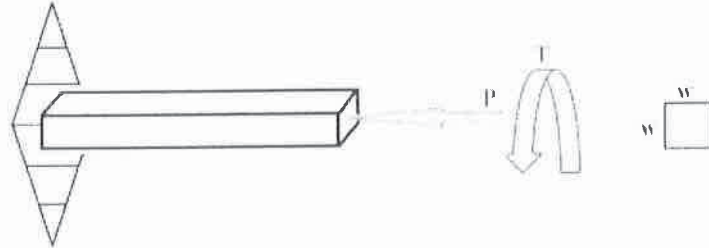
a) What is the minimum allowable dimension **w** if $\sigma_{yielding} = 480$ MPa?   (10 marks)
b) What would your answer be if the Von-Mises stress criterion is used?   (10 marks)

5. 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 1200 mm away from where the loads are applied. Assume the applied loads are acting at the shear center of the section.   (20 marks)
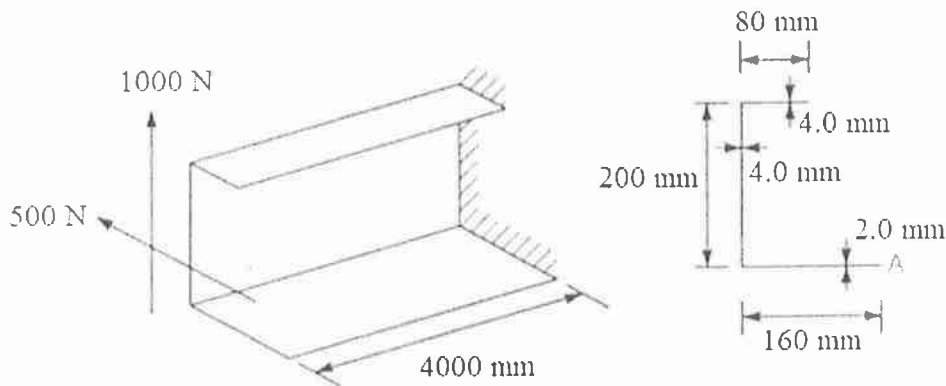
6. The figure below shows a three cell thin wall wing box made from a material whose shear modulus G is 90 GPa. The wing box is subjected to a constant clockwise torque of 48,000 N.m. The upper panels of the box have a constant thickness of 3.5 mm, while the lower panels have a thickness of 2.5 mm. All vertical panels are 2.0 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)
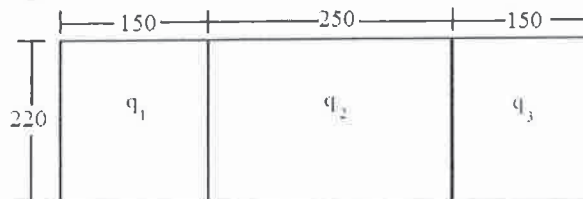
All dimensions shown are in mm.

7. An aircraft wing skin panel which can be modeled as a semi-infinite plate, has an edge crack of length 0.25 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 238 N/mm^2 normal to the crack. If the panel is made from a metal alloy with fracture toughness of 2400 N/mm$^{3/2}$ and a crack growth rate of 37×10^{-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)

8. The horizontally symmetric, constant wall thickness (1.75 mm) thin walled idealized wing box shown below is subjected to a vertical shear force of 15,000 N acting upward. Assume wall 2-3 to be semicircular and take areas for booms 1 and 4 to be equal to 750 mm^2 and booms 2 and 3 to be equal to 600 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)