National Exams May 2012

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.

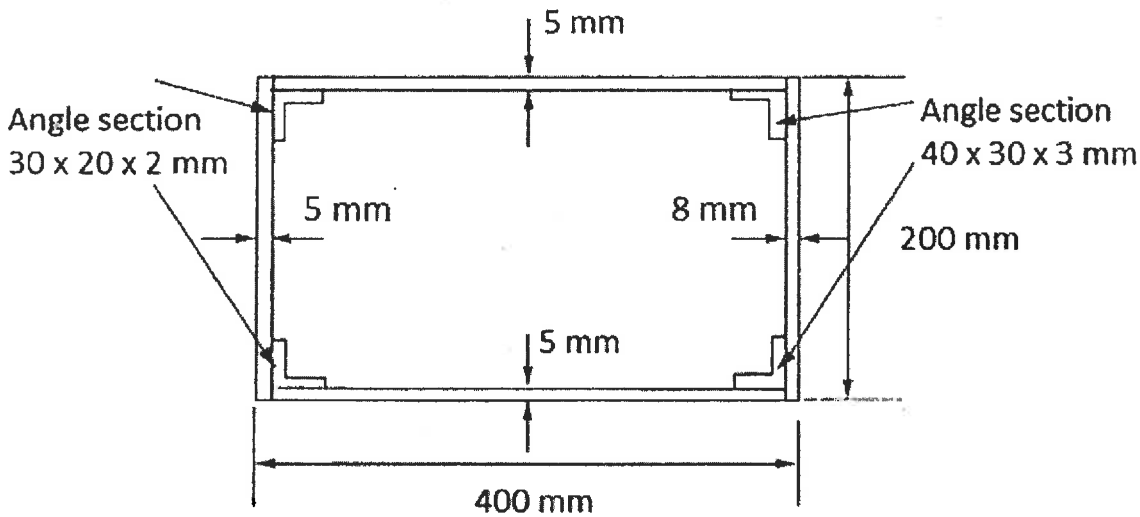
3. Answer **any** five questions.

4. All questions and sub-questions are of equal value.

1- The thin wall box beam shown below is symmetric with respect to a horizontal x-axis and is subjected to a constant torque T = 55 KN.m acting clockwise and an upward vertical shear load of 20 KN acting half way between the left and the right wall. The four corner elements have a thin wall right angle cross section of outer dimensions and wall thickness as shown.

a) Obtain the location and magnitude of the maximum shear stress in the section.

b) Determine the location of the shear centre with respect to the left wall.



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 5,000 cycles is adequate to detect the crack before it grows to a critical length leading to panel fracture.

3- A cantilever bar (rigidly supported at one end) of solid square cross-section (**a** by **a**) is subjected at its free end to a compressive axial force of magnitude P = 350 x 10^3 N acting at the centroid of the section and a torque T = 15 x 10^3 N.m. This bar is to be designed in accordance with the maximum shear stress failure criterion, with a safety factor of 3.

a) What is the minimum allowable dimension **a** if $\sigma_{yielding}$ = 350 MPa?

b) What would the dimension **a** have to be if P was replaced by a bending moment in a vertical plane of the same magnitude as T?

4- A composite laminate is made from layers of unidirectional carbon fibre reinforced laminae oriented at 0 degree from the x load direction. The longitudinal modulus of the laminate is 200 GPa, the transverse modulus is 15 GPa, the shear modulus is 8 GPa, and the longitudinal to transverse Poisson ratio is 0.3. If the laminate is subjected to strains ε_x = 300x10^{-6}, ε_y = 100x10^{-6} and γ_{xy} = 75x10^{-6}

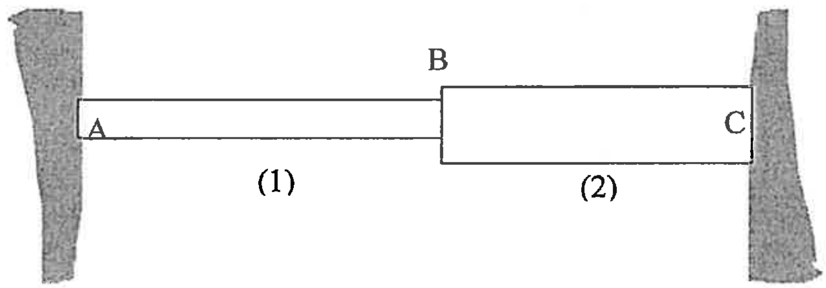
a) Determine the resulting normal and shear stresses.

b) Answer the question in a) if the fibers were oriented at +45 degrees.

5- 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 = 200 GPa, cross-sectional area A_1 = 5 cm^2, length L_1 = 120 cm, and coefficient of thermal expansion $\alpha_1 = 12 \times 10^{-6}$/°C. Rod (2) has a modulus E_2 = 100 MPa, cross-sectional area A_2 = 15 cm^2, length L_2 = 100 cm, and coefficient of thermal expansion $\alpha_2 = 17 \times 10^{-6}$/°C.

a) Determine the axial stresses in the rods if their temperature is raised by 80 °C.

b) Determine whether joint B moves to the right or left and by how much?



6- An aircraft fuselage section of circular shape has a radius r = 510 mm, a uniform wall thickness t = 1 mm and is stiffened by 16 equally-spaced stiffeners that have cross sectional areas equal to 100 mm^2 each. Calculate the hoop stress σ_H and the axial stress σ_A in the skin panels as well as the axial stress σ_s in the stiffeners if an internal pressure p equal to 65 KPa is applied. Assume all materials to be aluminum with a Poisson's ratio ν = 0.30.

7- A subsonic aircraft has a wing with a surface area S = 10 m^2, a half span b = 8 m and a lift curve slope $\partial C_L/\partial\alpha$ = 4/rad. The distance separating the aerodynamic centre of the wing and the twist centre of its torque box is 250 mm. Assuming that the aircraft was designed for an ultimate speed of 300 m/s at sea level flight where the air density ρ = 1.225 kg/m^3:

a) Adopting a 2D flow approximation, what should the minimal torsional rigidity (GJ) of the wing torque box be in order to avoid torsional divergence?

b) Assuming the torque box was a 500 mm x 500 mm square thin wall of uniform thickness t and made from an aluminum alloy with G = 27 GPa, determine the minimum wall thickness t_{min} that would provide the above minimal torsional rigidity.

8- A metallic aircraft component with a yielding strength of 340 MPa is subjected to a triaxial stress state of σ_x = -80 MPa, σ_y = 120 MPa, σ_z = 120 MPa, and τ_{xy} = -40 MPa. If the component is of isotropic, ductile material, predict whether such stresses will cause yielding, given a safety factor of 2, according to the:

a) Maximum shear stress failure criterion

b) Von-Mises failure criterion.