National Exams May 2002

Mec-B8 AIRCRAFT MATERIALS AND 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 two** of the first four questions **and any three** of the last four questions.

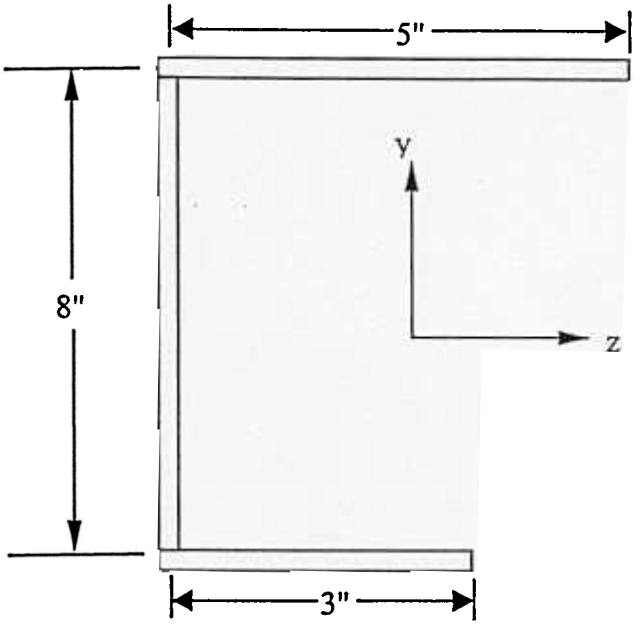
4. Every problem is worth 20 marks.

1- The thin-walled open section shown below is subjected to a vertical force of 2500 lb acting through the shear center.

a) Plot the shear flow distribution in the thin walls of the section. All of the walls have the same thickness of 0.25 inch. All the dimensions are to the midplanes of the webs and flanges.

b) Locate the shear center relative to the vertical web.

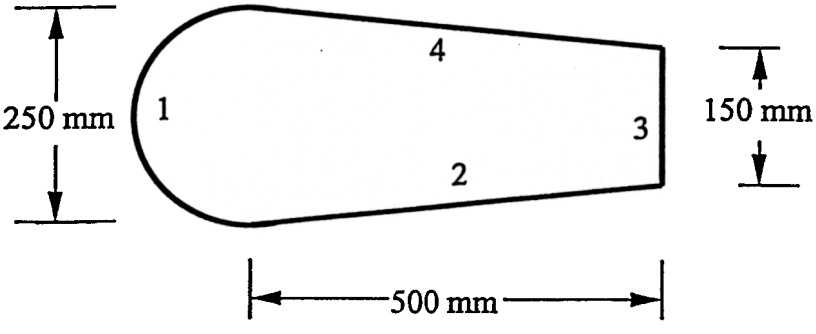
c) Calculate the maximum shear stress in the section if the shear force acts through the vertical web instead of through the shear center.




2- The wing torsion box shown below is symmetric with respect to the x-axis and is subjected to a constant torque T = 30000 N.m. acting clockwise.

a) Calculate the shear flow q in walls 1, 2 ,3 and 4. The thickness of each wall is as follows: $t_1 = 2$ mm, $t_2 = 4$ mm, $t_3 = 3$ mm, and $t_4 = 4$ mm. Wall 1 is semi-circular.

b) What is the maximum shear stress and in which wall does it occur?




ALL DIMENSIONS SHOWN ARE MEDIAN DISTANCES

3- A cantilever bar (rigidly supported at one end) of solid square cross-section (w by w) is subjected at its free end to a compressive axial force of magnitude $P = 60 \times 10^3$ lb and a torque $T = 20 \times 10^3$ lb.in. This bar is to be designed in accordance with the maximum-shear-stress criterion of failure, with a safety factor of 2.

a) What is the minimum allowable cross-sectional dimension w if $\sigma_{yielding} = 40$ ksi ?

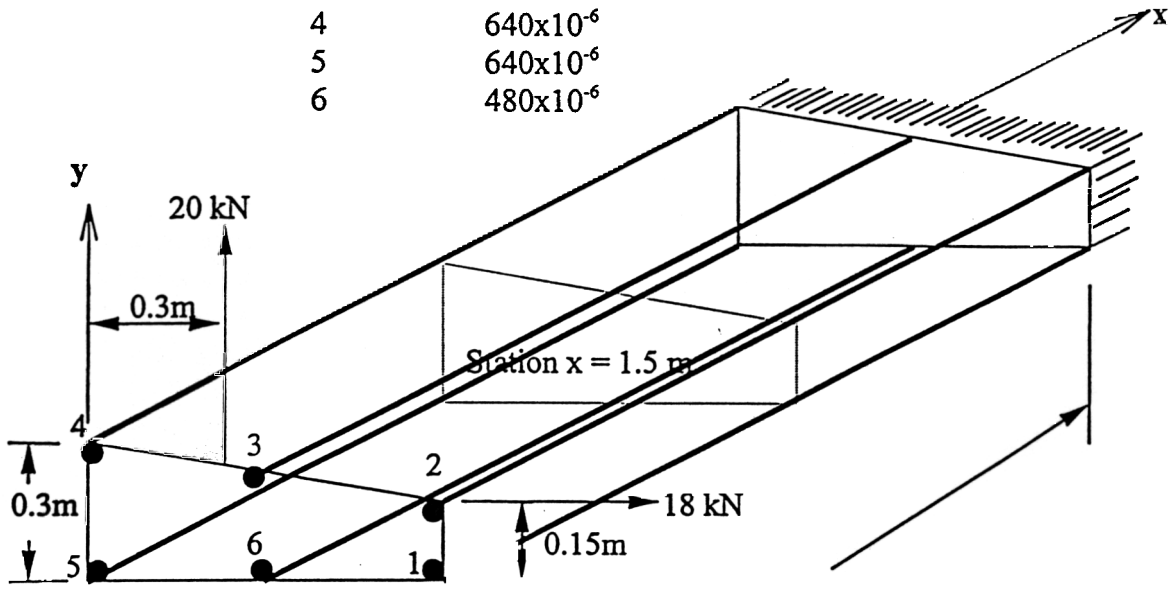
b) What would your answer be if the Von-Mises stress criterion is used.

4- The figure below shows a cantilevered, idealized wing box with shear loads applied at the free end as shown. The cross-sectional areas of the stringers are listed. Assuming webs are only effective in shear:

a) find the shear flows in the webs at station x = 1.5 m, and

b) determine the stringer loads at the same station.

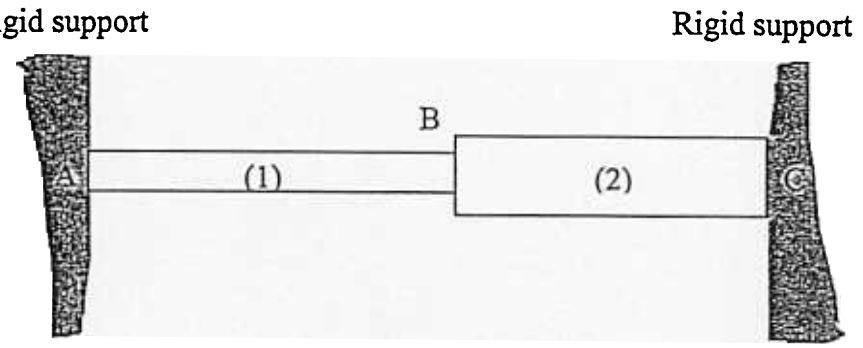
| Stringer | Area ($m^2$) |
|---|---|
| 1 | $320 \times 10^{-6}$ |
| 2 | $320 \times 10^{-6}$ |
| 3 | $480 \times 10^{-6}$ |
| 4 | $640 \times 10^{-6}$ |
| 5 | $640 \times 10^{-6}$ |
| 6 | $480 \times 10^{-6}$ |



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 $E_1$ = 25,000 ksi, cross-sectional area $A_1$ = 3.5 in$^2$, length $L_1$ = 60 in., and coefficient of thermal expansion $\alpha_1 = 6 \times 10^{-6}$/°F. Rod (2) has a modulus $E_2$ = 10,000 ksi, cross-sectional area $A_2$ = 4.0 in$^2$, length $L_2$ = 50 in., and coefficient of thermal expansion $\alpha_2 = 12 \times 10^{-6}$/°F.

a) Determine the axial stresses in the rods if the temperature of both is raised by 100 °F.

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




6- An orthotropic composite material system has the following lamina properties

$$E_{11} = 130 \text{ GPa}$$
$$E_{22} = 13 \text{ GPa}$$
$$G_{12} = 9 \text{ GPa}$$
$$\nu_{12} = 0.3$$

a) Determine the various entries in the 0° lamina stiffness matrix [C]. Recall ($[\sigma] = [C][\varepsilon]$)

b) Evaluate the transform stiffness matrix [Q] for a 90° ply.

c) Evaluate the transform stiffness matrix [Q] for a 45° ply.

d) Determine $\sigma_x$ , $\sigma_y$ , $\tau_{xy}$ for a 90° ply if $\varepsilon_x$ , $\varepsilon_y$ , $\gamma_{xy}$ are given by 0.0009, 0.005 and –0.001 respectively.

7- A continuous and aligned fiber-reinforced composite is to be produced consisting of 60% volume of carbon fibers and 40% volume of a polymer matrix; mechanical characteristics of these two materials are as follows (see next page):

| | Modulus of Elasticity GPa | Tensile Strength MPa |
|---|---|---|
| Carbon fiber | 190 | 2500 |
| Polymer matrix | 8 | 85 |

Assume that the composite described has a cross-sectional area of 350 $mm^2$ and is subjected to a longitudinal load of 50,000 N.

a) Calculate the fiber-matrix load ratio.
b) Calculate the actual loads carried by both the fibers and the matrix.
c) Compute the magnitude of the stress on each of the fiber and matrix phases.
d) What strain is experienced by the composite?

8- An isotropic ductile solid with a yielding strength of 250 MPa is subjected to the state of stress shown below. Predict whether such stresses will cause failure according to the:
a) maximum shear stress theory
b) energy of distortion theory.