Midterm Exam 2013

Preview (1) (20%) **Basic Composite Behaviour**
(2) (30%) **Basic Laminate Behaviour**
(3) (40%) **Stress and Deformation Under Load**
(4) (10%) **Short Answer Question**
(5) (0%) **Philosophy**

If you are not sure about your answer(s), you should provide comments or reasoning.

1. (20%) Basic Composite Behaviour

A $[0_2/\pm 25/0]_s$ laminate (10 layers) with a core of 1cm (2zc=1cm) is designed using T300/N5208 carbon epoxy composite material with the following properties:

$E_x = 181\ GPa$ $Q_{xx} = 181.81\ GPa$
$E_y = 10.3\ GPa$ $Q_{yy} = 10.35\ GPa$
$E_s = 7.17\ GPa$ $Q_{xy} = 2.90\ GPa$
$\nu_x = 0.28$ $Q_{ss} = 7.17\ GPa$ *ply thickness, ho = 0.125mm*

The resulting [A] and the [a] matrix for this laminate are as follows:

$$[A] = \begin{bmatrix} 200.4 & 15.18 & 0 \\ 15.18 & 16.68 & 0 \\ 0 & 0 & 20.53 \end{bmatrix} \quad MPa-m \qquad [a] = \begin{bmatrix} 5.36 & -4.88 & 0 \\ -4.88 & 64.40 & 0 \\ 0 & 0 & 48.71 \end{bmatrix} \quad 1/GPa-m$$

$$[D] = \begin{bmatrix} 5680.4 & 421.2 & 17.1 \\ 421.2 & 468.7 & 4.4 \\ 17.1 & 4.4 & 572.1 \end{bmatrix} \quad N-m \qquad [d] = \begin{bmatrix} 0.189 & -0.169 & -0.004 \\ -0.169 & 2.286 & -0.013 \\ -0.004 & -0.013 & 1.748 \end{bmatrix} \quad 1/kN-m$$

This laminate is used to design a long beam in the 1-direction. We want to compare this design to a solid bar of aluminum to see which has the higher bending stiffness. Each has a width of b=2cm and length= 2m (in the 1-direction for the composite beam).
The aluminum bar has a rectangular cross section with thickness h=1cm and Young's Modulus E=73 GPa.

Calculate the 2 bending stiffnesses and determine which beam has the highest bending stiffness in the long direction.

2. (30%) Basic Laminate Behaviour

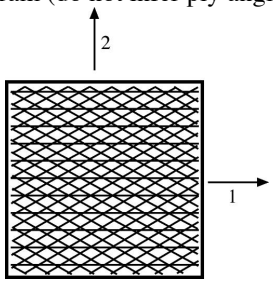
Consider the following six laminates:

A: $[0_5/\pm30/\pm45/90]_S$
B: $[90/0_2/(\pm45)_2/0_3]_S$
C: $[0_2/90/0_2/90]$s
D: [+30/-30/+30/-30]s
E: [-30/+30/-30/+30]s
F: $[+30_2/-30_2]$s

(a) Change one ply angle (one number) in laminate ***A*** such that it will now have an A_{22} stiffness the same as laminate ***B***.
(b) Reorder the plies of laminate ***C*** (without changing the angles of those plies) in order to maximize the D_{11} term.
(c) Order laminates ***D***, ***E*** and ***F***, from highest to lowest, for bending stiffness in the 2-direction.
(d) Which, of the 6 laminates, are cross-ply laminates.

3. (40%) Stress and Deformation Under Load

A composite laminate is provided for you, but the layup is not known, except that it is a symmetric layup. The plate is approximately square, as shown in the diagram (do not infer ply angles from this diagram).



Material: Kevlar/Epoxy
Known material property matrices:

$$[A] = \begin{bmatrix} 46.54 & 10.00 & 5.57 \\ 10.00 & 40.92 & 11.13 \\ 5.57 & 11.13 & 10.51 \end{bmatrix} \quad MPa-m \qquad [a] = \begin{bmatrix} 23.25 & -3.27 & -8.85 \\ -3.27 & 34.78 & -35.09 \\ -8.85 & -35.09 & 136.94 \end{bmatrix} \quad 1/GPa-m$$

$$[D] = \begin{bmatrix} 8.77 & 1.18 & 0.64 \\ 1.18 & 2.85 & 1.28 \\ 0.64 & 1.28 & 1.25 \end{bmatrix} \quad N-m \qquad [d] = \begin{bmatrix} 0.121 & -0.041 & -0.020 \\ -0.041 & 0.659 & -0.651 \\ -0.020 & -0.651 & 1.475 \end{bmatrix} \quad 1/N-m$$

3(a) Does this laminate have a balanced layup? State the reason for your answer.

3(b) Given the loading condition,

$N_1 = 10{,}000 \quad N_2 = 0 \quad N_6 = 0 \qquad N/m$

qualitatively describe the resulting deformation of the laminate?
(similar to the diagrams depicted on page 34, Figure 3.8, of the notes).

3(c) Given the loading condition,

$N_1 = 0 \quad N_2 = 100 \quad N_6 = 1{,}000 \qquad N/m$

which direction will have the highest off-axis axial compressive strain (calculate)?

4. (10%) Short Answer Question

A laminate is subjected to positive bending load in the 1-direction. The stresses are shown here:

Ply Number	θ (degrees)	On-Axis stresses at ply centroid		
		σ_x(MPa)	σ_y(MPa)	σ_s(MPa)
8	?	365.4	5.2	0
7	?	-5.3	20.2	0
6	?	348.6	4.9	0
5	?	-5.1	19.2	0
core				
4	?	5.1	-19.2	0
3	?	-348.6	-4.9	0
2	?	5.3	-20.2	0
1	?	-365.4	-5.2	0

What is the probable laminate layup? Choose between the following 6 choices and state why:

(a) [0/45/-45/90]s
(b) [0/90/0/90]s
(c) [90/0/90/0]s
(d) $[(45/-45)_2]$s
(e) $[(-45/45)_2]$s
(f) [0/45/0/-45]s

(0%) Philosophy

"There's a bit of magic in everything, and some loss to even things out"

"Take a walk on the wild side"

'Life is like Sanskrit read to a pony"

Lou Reed, *New York rock singer 1942 to October 27, 2013*