Mechanics of Composite Materials **November 4, 2014**
Mechanical Engineering MECH 530 Due : **November 18, 2014 - No Resubmission**

Project, Assignment #6
Design Case Studies

This assignment is meant as an exercise in design, using your knowledge of composite materials and your computer program (that should be in good working order). Be aware that this assignment involves using your judgment and the answer you come up with may not be unique.

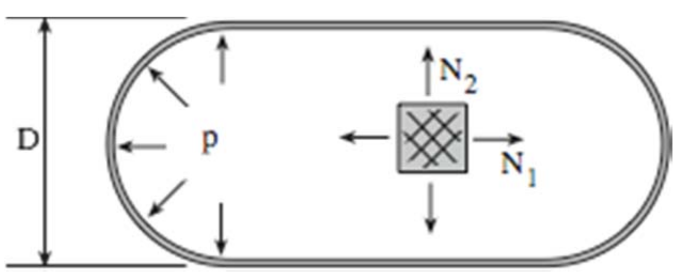
DESIGN #1) Design of a filament wound pressure vessel
A pressure vessel is to be designed using a wall made with a [±Θ]s laminate (4 total layers). Due to the pressure, p, inside the cylinder, the classical pressure vessel problem tells us that this leads to loads in the walls according to:

$$N_1 = \overline{\sigma}_1 h = pD/4 \quad N_2 = \overline{\sigma}_2 h = pD/2$$

(there is more hoop stress than axial). Use Kevlar (Kevlar/epoxy) material and the load case of

$$p = 1.25MPa \quad D = 8cm$$

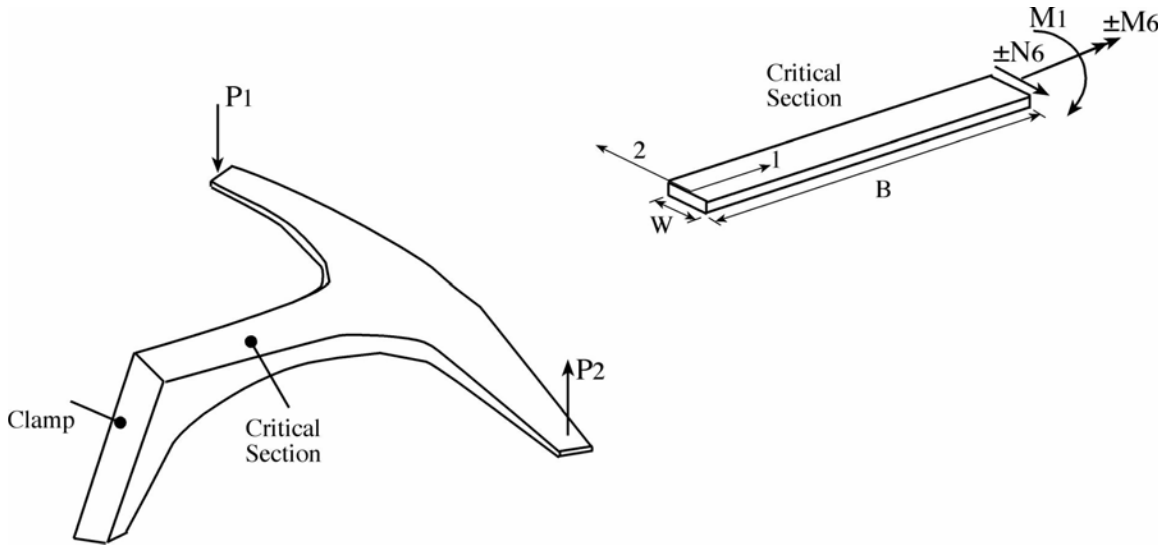
Find the optimum ply angle, □, to the nearest degree (not fractions of degrees) that will give the highest safety factor in all 3 of the failure criteria (i.e., maximize the lowest of the 3 safety factors for ply angle). Submit a complete output of your program for your final design only.



DESIGN #2) Design of a Laminate
Design any laminate using only four different ply angles according to the following rules:

- You may only choose among ply angles 0°, 25°, -25°, 55°, -55° and 90°.
- You must choose <u>AT LEAST FOUR DIFFERENT PLY ANGLES</u> among the 6 choices.
- Your laminate must be symmetric (thus minimum 8 layers, or 7 layers if designed inventively)
- You must use Fiberglass Epoxy material, with NO core material
- Design a laminate where the Bending stiffness in the 1-direction is approximately the same as the bending stiffness in the 2-direction, $D_{11} = K\ D_{22} \approx 1.0\ D_{22}$, (the factor does not have to be exactly 1.00, but can be in the range $0.90 < K < 1.10$).

DESIGN #3) Design of a hockey stick blade



You are required to come up with a lay-up and material for a sandwich beam construction. The problem is that of the critical region of a bicycle handlebar with a thick stem section. We can estimate the expected complicated loading condition, and we also know the nominal dimensions. So we will restrict ourselves to a design with the following known quantities:

a) Symmetric Lay-up with honeycomb core thickness = 0.15cm (zc = half core = 0.075cm = 0.00075 m). This is an approximately 1/16 inch balsa wood core.

b) Loading condition: Two loading cases will be considered: Normal loading condition and Abnormal loading condition. Keep in mind that the behavior of the structure is much more complex than depicted here. Approximate loads can be obtained by an analysis of the handlebar.

Case 1: Normal Loading Condition (all M_i and N_i are negative)

$\mathbf{M_1}$= -1,000 Nm/m $\mathbf{M_2}$= -100 Nm/m $\mathbf{M_6}$= -100 Nm/m
$\mathbf{N_1}$= -22,400 N/m $\mathbf{N_2}$= -3,000 N/m $\mathbf{N_6}$= -2,000 N/m

Case 2: Normal Loading Condition

$\mathbf{M_1}$= -980 Nm/m $\mathbf{M_2}$= -98 Nm/m $\mathbf{M_6}$= -110 Nm/m
$\mathbf{N_1}$= -20,800 N/m $\mathbf{N_2}$= -2,800 N/m $\mathbf{N_6}$= -2,200 N/m

Assume: **W**=3cm, **B**= 10cm

c) We do not want the structure to fail for either load case, and we want a safety factor. There should be **no "R-factor" less than 2.0** anywhere in either Hashin, Quadratic (Tsai-Wu), or Maximum Stress failure criteria in either load case. In other words, one ply orientation must pass both load cases.

Find a design that meets the above failure criteria restrictions. The following are quantities to be determined by your design:

- Number of layers.
- Material properties, you may choose any one of the five materials from the database.
- The ply orientation. By now, you should have some feel about how to choose an appropriate ply orientation.
- Also, I want to see who will come closest to the lightest design. You can calculate this by multiplying the material density ("rho" in data sheet) by the ply thickness (ho) by the number of plies you have chosen, and finally by the area **B*W**. This will give you a mass.
- (Note that rho is in g/cm3 and **ho** is in mm so convert your final units to grams).

  Mass = (rho) × (#layers) × (ho) × (LW)

In the case of a tie for lightest design (same material and number of layers), the winner goes to "highest safety factor for the same number of layers".

For Design Problem #3, submit a complete report from your <u>final program output only</u> (not every attempt) **and** a short handwritten summary (less than a page) of (1) number of layers (2) material chosen (3) ply orientation, (4) mass of your design, and (5) Minimum safety factor results for load cases I and II.

There is no single correct answer; many ply orientations will satisfy the criteria.