FINAL QUESTIONS

MEGN498A

Due May 10, 2021 by 2pm submitted as a single file (PDF) on CANVAS.
No late exams accepted.

Read directions and questions carefully. Only use material provided by or generated from this course, nothing outside or online, as well as a graphing or scientific calculator (or equivalent). Write all steps to get to the final answer out clearly and neatly, box-in final answers and put units (if required) to receive full credit.

Please write out the following phrase, along with your name and signature at the top of your submitted exam to signify you followed the rules. Failure to do will result in a 0 on the final.

I followed the Mines Honor Code on this exam, I did not receive nor provide aid and this work is 100% my own. [– Printed Name & Signature]

Question 1: (6 points)

True or False, (1 point each):

(A) When shear force changes its sign from positive to negative, bending moment is minimum.

(B) If an aircraft has a tail load that acts upwards, the CG of the aircraft is far aft of the aerodynamic center.

(C) Thermal loading does not affect shear stress in a linear, elastic, isotropic, homogeneous material.

(D) Applied torque cannot be reacted with internal shear flow in closed cross-sections.

(E) In a steady pull-out of an airframe load, the lowest point of the pull out provides the highest load factor on the aircraft.

(F) A material with σ_x as the only nonzero stress component will always have only one nonzero component of strain.

Question 2: (14 points)
WITHOUT the aid of mathematical software (although you can use it to check your answers), write out the full solution to the following:

A component on a deep space satellite in equilibrium has the following strain field (assume no body forces and all other strains are zero):

$$\epsilon_x = 6x^2y$$
$$\epsilon_y = 6xy$$
$$\gamma_{xy} = 3y^2 + 2x^3$$

with the boundary conditions $u_y(0,0) = 0$, $u_x(0,0) = 0$ and $u_x(0,3) = 0$ in units of inches.

a. Is this an admissible solution? SHOW and check ALL equations for full points.

b. Assuming it is an admissible solution, what is the overall displacement field? Show all work.

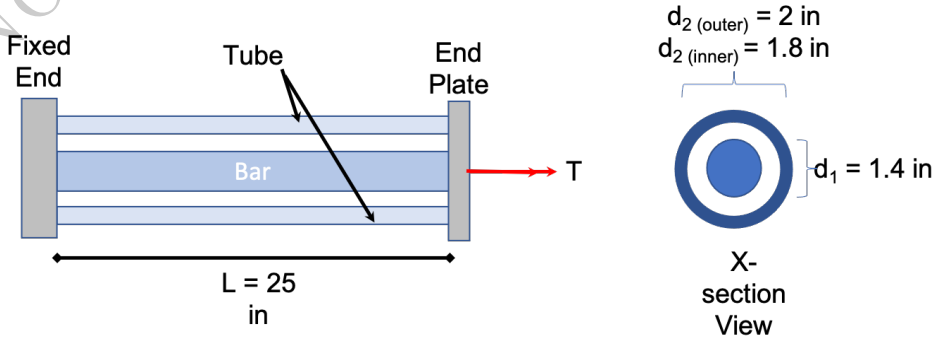
c. Write out the stress field in correctly labeled units, assuming the material is titanium and (as it is in deep space) a temperature change has occurred such that $\Delta T = -200\ K$. Use the constitutive values for that material given on page 23 of the course notes. Put your final answer in matrix form. If you need to look up unit conversions online, you may, but no other online help is allowed.

Question 3: (12 points)
Write out the full solution to the following (be sure to show all equations and steps in the hand-written part even if you use mathematical software to help calculate):
A solid aluminum bar is enclosed by an aluminum tube as part of a drive system on an unpersoned helicopter. The solid bar has a diameter of 1.4 in and the tube has an outer diameter of 2 in and inner diameter of 1.8 in. The bar and tube both are held rigidly by a support on one the end and by an end plate on the other. This bar system has a length of 25 in and is twisted by a torque of 1000 lb-in acting on the end plate.

a. Determine the maximum shear stresses in the bar and tube.

b. Determine the rate of twist and angle of rotation (in degrees) of the end plate, assuming a shear modulus of 3.5×10^6 psi.

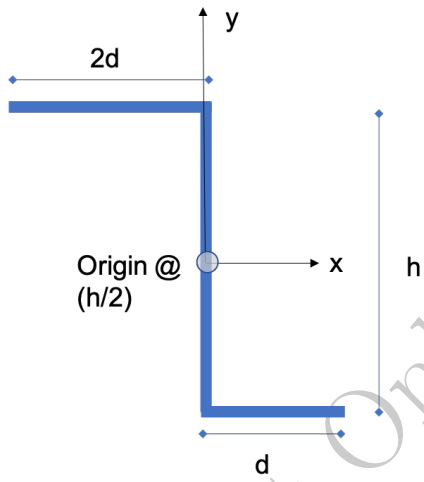
c. Determine the torsional stiffness of the complete bar system.



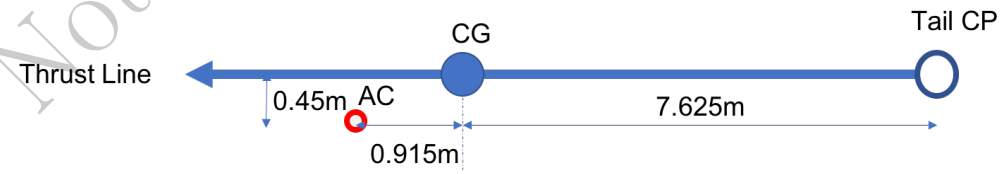
Question 4: (14 points)
Given the Z-beam with constant thickness t and assuming it is in the principal axes has a bending moment of 3,000 Nm applied (M_x) in the plane of the web. Write out the full solution to the following (be sure to show all equations and steps in the hand-written part even if you use mathematical software to help calculate):

a. Determine the centroid and second moment of areas for the cross-section.

b. Calculate and sketch of direct stress in the beam cross-section.



Question 5: (10 points)
An aircraft flies at sea level in a correctly banked turn of radius 610 m at a speed of 168 m/s. The figure above shows the relative positions of the CG, aerodynamic center of the complete aircraft minus the tailplane, and the tailplane center of pressure for the aircraft at zero lift incidence. Calculate the tail load necessary for equilibrium in the turn, showing all equations used and steps (with appropriate units). The necessary data for the plane are given as follows:
Weight, W = 133,500 N, Wing area, S = 46.5 m^2, Wing mean chord, $\bar{c}$ = 3.0 m, $dC_L/d\alpha$ = 4.5/rad, $C_D = 0.01 + 0.05\ C_L{}^2$,$C_{M,0} = -0.03$



Question 6: (6 points)
Using mathematical software (turn in with your exam) given the following 3 composites:

Carbon-epoxy
$E_l = 140$ GPa
$G_{lt} = 7.0$ GPa
$E_t = 10.0$ GPa
$\nu_{lt} = 0.3$

Boron-aluminum
$E_l = 235$ GPa
$G_{lt} = 45$ GPa
$E_t = 135$ GPa
$\nu_{lt} = 0.3$

Glass-epoxy
$E_l = 43$ GPa
$G_{lt} = 4.5$ GPa
$E_t = 9.0$ GPa
$\nu_{lt} = 0.27$

Plot the following 3 plots, each plot should show all 3 composites above. Be sure to label axes correctly to receive full points:

a. E_x/E_t as a function of θ from 0 to 90 degrees.

b. G_{xy}/E_t as a function of θ from 0 to 90 degrees.

c. ν_{xy} as a function of θ from 0 to 90 degrees.

Answer the following questions in a sentence or two for 1 point bonus each:

a. Which composite is the most anisotropic? Which is the least? Why?

b. Of all composites, which orientation (angle of θ) produces the best in-plane shear properties?

c. Which composite longitudinal stiffness most strongly depends on loading direction in relation to fiber orientation?