**PLEASE NOTE: Answer 3 out of the 4 problems. In case you answer the 4 problems, clearly state which 3 problems you want to be graded.**

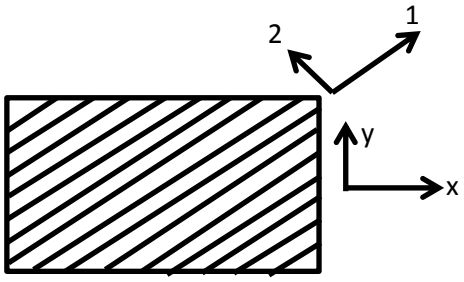
## Problem #1

A T-300 carbon fiber reinforced epoxy thin plate with the fibers running at 45 degrees as shown in the schematic is used as part of a laminated structure. The plate will be adhered to the other laminas of the composite structure using a thin layer of adhesive and heating at 400 $^{o}$C. The final laminated structure is used at ambient temperature.

1) Calculate the thermal strains in the 1,2 coordinate system at ambient temperature.
2) Calculate the stresses in the 1,2 coordinate system.
3) Calculate thermal strains $\varepsilon_{xx}$ and $\varepsilon_{yy}$ and $\gamma_{xy}$.
4) Calculate $\sigma_{xx}$, $\sigma_{yy}$ and $\tau_{xy}$.

List and justify your assumptions

DATA GIVEN




$\alpha_{11} = -0.5 \times 10^{-6}$ m/m $^{o}$C

$\alpha_{22} = 12 \times 10^{-6}$ m/m $^{o}$C

$E_{fiber} = 220$ GPa

$E_{matrix} = 3.6$ GPa

$G_{12} = 3.254$ GPa

$\nu_{12}$ calculated using the rule of mixtures

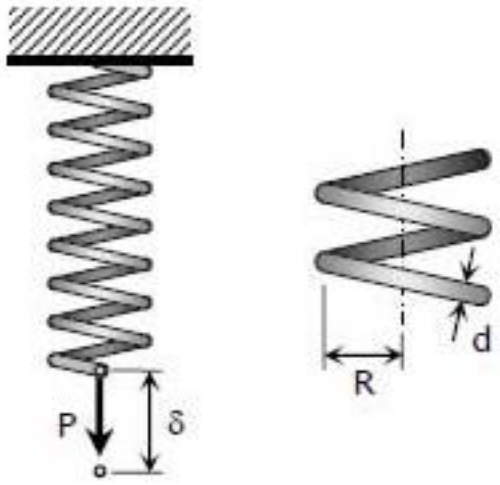
$\nu_{21} = \nu_{12} E_{22}/E_{11}$, where $E_{11}$ and $E_{22}$ are the longitudinal and transverse modulus of the plate

$V_f = 60\%$ (volume fraction of the fibers)

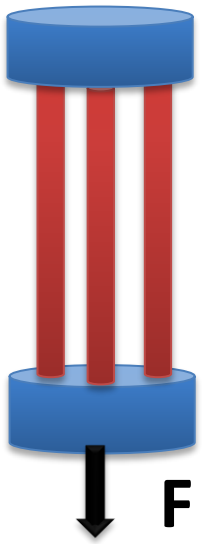
**Problem #2**

(a) Derive the equation for maximum shear stress in a helical tension spring with *n* number of turns using the parameters given in the schematic. Neglect the curvature of the spring. Where does this stress occur?

(b) Derive the equation for the deflection $\delta$ of the spring. Hint: use Castigliano's theorem (energy method).



## Problem #3




Consider a system in which three cables are attached to two rigid plates. The top plate is fixed. All cables have the same elastic properties (E = 100 GPa, ν = 0.28) but have different yield strength and ultimate tensile strength as shown in table below. All cables have an elastic plastic behavior with linear hardening (the linear hardening coefficient is $H^p$ = 50 GPa, i.e. after the yield point the plastic strain is related to stress as follows $\sigma = H^P \varepsilon^p$) The cross sectional area of all cables is the same and is equal to 25 $mm^2$. All cables have the same length of 1 m.

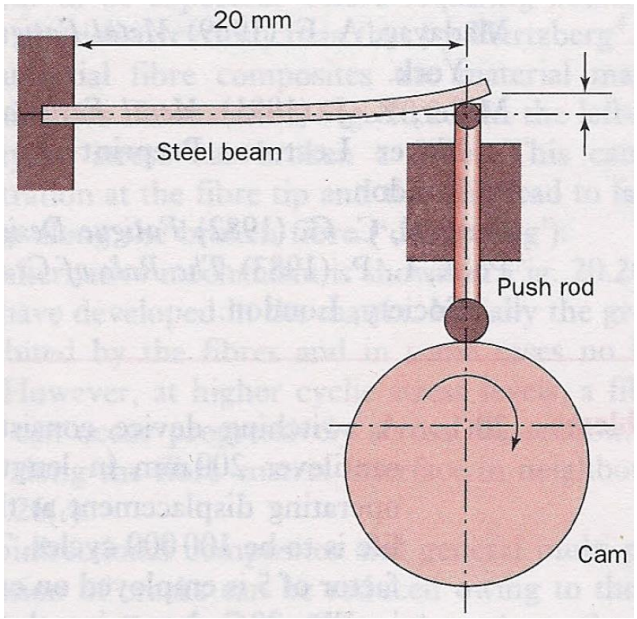
| **Cable 1** | **Cable 2** | **Cable 3** |
|---|---|---|
| Yield strength=250MPa. | Yield strength=300MPa. | Yield strength=600MPa. |
| Ultimate tensile stress=300MPa. | Ultimate tensile stress=550MPa. | Ultimate tensile stress=900MPa. |

1) Upon gradually imposing a force F on the rigid plates up to the value of 23kN, draw the displacement versus force diagram of the entire structure. Clearly indicate and compute each points and slopes on the diagram.

2) If now one tries to gradually increase the force up to 27kN.
   - Discuss what could happen to the structure (each event).
   - Compute and plot the load versus displacement diagram.

## Problem #4

As part of the mechanism of a machine, a cam is used to cause a metal beam to oscillate, as shown in the attached figure. The design of the cam is such that the beam's deflection at the end, as measured from the straight and undeflected position, varies between 1 mm and 3 mm on the upper side. Calculate the minimum cross-sectional height of the beam to avoid fatigue failure. You can use any established method (e.g., Gerber, modified Goodman, or Soderberg) to account for the effect of the mean stress – only one method is expected. The yield stress is 200 MPa, tensile strength is 350 MPa, fatigue strength for fully reversed cycling is 100 MPa, and the Young's modulus is 207 GPa. Please use a fatigue strength safety factor of 1.8.




Deflection varies between
1 mm and 3 mm