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 steel rod (AB) and a copper rod (BC) are connected at B and fixed between two rigid walls. These two rods were installed at room temperature without any residual stress. Consider the following cases:

1. If the temperature is increased by 10°C, please determine the stress in rod AB.
2. A torque T = 200 Nm is applied at B. Please determine the shear stress due to torque at D.
3. Please write down the state of stress (the six components of the stress state) at point D.
4. Please show the non-zero stress components on a cubic volume element of the material at point D. Note that the faces of the cubic volume element should be aligned to the coordinate system given in the figure.
5. Consider the stress state in the x-z plane. Find the inclined plane on which the shear stress is zero. Also, what is the normal stress on that plane?

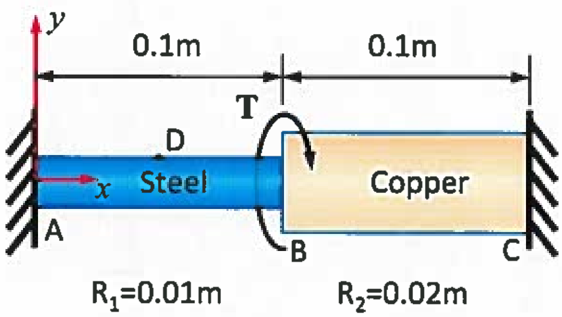


Figure.

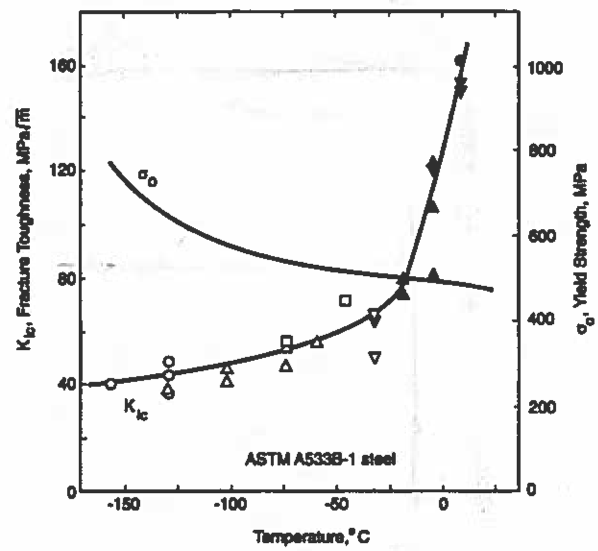
Mechanical properties of steel and copper.

	Modulus E (GPa)	Poisson Ratio's ν (*)	CTE α
Steel	200	0.3	12×10^{-6}
Copper	120	0.3	17×10^{-6}

* To simplify the problem, we assume steel and copper have the same Poisson's ratio.

Problem # 2:

1. Gas cylinders with Argon will be delivered from a US port (average temp of 15⁰C) to McMurdo station in Antarctica (average temperature -15 ⁰C). Each cylinder is made from ASTM A533B-1 steel and is pressurized to 10 MPa. By the time each cylinder arrives to McMurdo the pressure will decrease to *7.5 MPa*. As the cylinders are secured on board, a torque (e.g. moment with direction parallel to the axial direction of the cylinder) $T = 1\ KN.m$ is also applied on each cylinder.



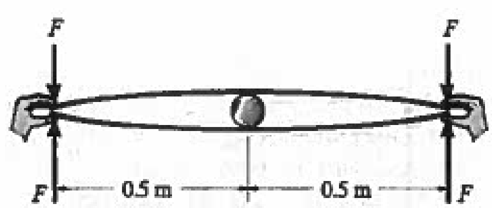
(a) If a surface crack has formed on the inner wall of one of the cylinders find the allowable ratio of crack length to cylinder thickness (a/t) so that fracture is prevented.

(b) Suggest changes in the design that would ensure that flaws with size of 10% of the cylinder wall thickness do not propagate.

Let: $E = 210\ GPa;\ \nu=0.3;\ K_I=\sigma\sqrt{\pi a};$
cylinder wall thickness, $t=0.2\ cm;\ r_{inner}= 5\ cm$

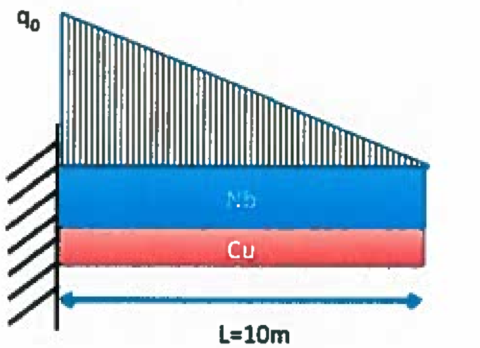
Problem #3

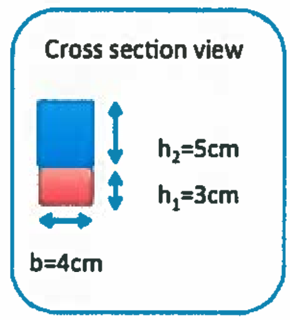
The two wooden meter sticks are separated at their centers by a smooth rigid cylinder having a diameter of 50 mm. Determine the force *F* that must be applied at each end in order to just make their ends touch. Each stick has a width of 20 mm and a thickness of 5 mm. The Young's modulus of the wood is 11 GPa.

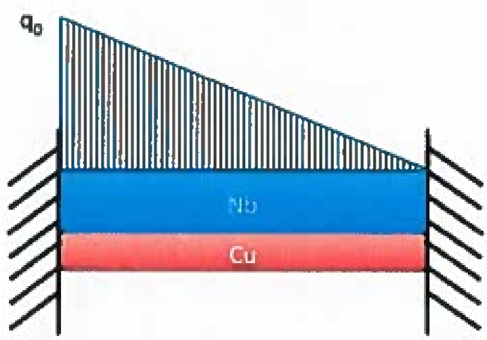


Problem #4

Consider the following composite beam made of two dissimilar materials; Cu and Nb. All dimensions and material elastic properties are provided in the figure and table here below.







Cu	Nb
E=110GPa	E=105Gpa
ν= 0.36	ν= 0.4
σ_y=120MPa	σ_y=105MPa

1. Consider first the configuration in which the beam is rigidly fixed on the left hand side and free on the right hand side. The beam is subjected to a spatially varying distributed load per unit length with maximum value q_0.

    a. Derive the mathematical expressions of the shear stresses and tensile stresses as a function of the beam geometry, elastic properties, applied load and position. You will clearly indicate the specific components of stress you are computing and explicitly show the coordinate system you are dealing with.
    b. Find the mathematical expression of the deflection of the beams' neutral axis.

2. Now consider the configuration whereby the beam is fixed at both ends (bottom picture of the figure). Assume both materials can be described as having an elastic-perfect plastic behavior and identify the maximum value of q_0 that can be prescribed prior to having any point in the beam yield plastically. Geometrically identify the position of such critical point. Clearly detail any assumption you wish to make and justify their plausibility. Make use of what you derived in part a and b.