ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2022 SESSION

Open Book examination Calculators: Models allowed only Duration of the examination: 3 hours

16-MC-A6 Advanced Strength of Materials

There are four (4) questions presented on two pages.

Question 1 (25 points)

The beam AB with the diameter $d_{AB} = 98$ mm is fixed at A and welded with the beam BC which has a rectangular cross section 50×75 mm (Figure 1).
The point C is retained by a vertical cable CD which has a circular section of diameter $d_{CD} = 7.5$ mm.

All members are made of steel with modulus of elasticity $E = 2*10^5$ MPa and Poisson's ratio $\nu = 0.3$.

By neglecting the energies due to shear force, compute the tensile force in the CD cable as a function of the vertical load P applied downward at B.

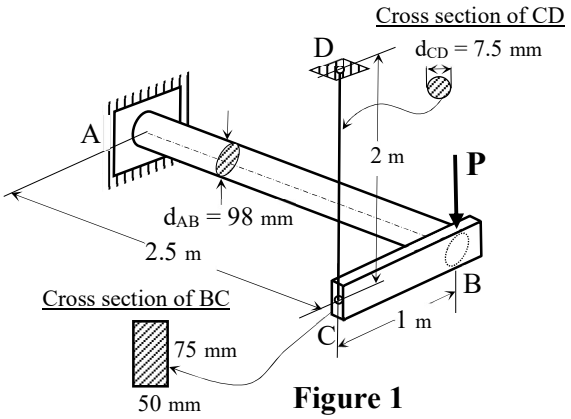

Figure 1

Question 2 (25 points)

The beam OABCD is fixed at O and D.
Two loads **P** are applied downward at A and C.

A load **2·P** is applied downward at B.

The dimensions of the cross section of the beam are given in figure 2.

The material of the beam is elastic perfectly plastic with the yield stress $S_Y = 250$ MPa.

8 pts a) Calculate the moment plastic ($\mathbf{M_P}$) of the section of the beam.

17 pts b) Calculate the fully plastic load P of the beam ($\mathbf{P_P}$).

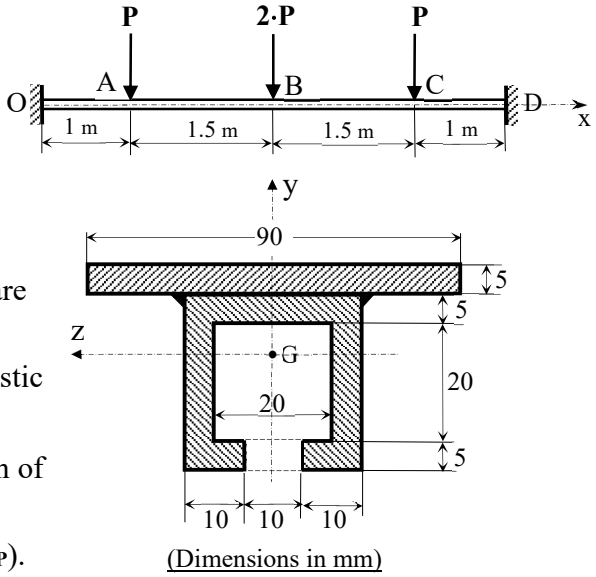

Figure 2

Question 3 (25 points)

A steel specimen with modulus of elasticity $E = 2*10^5$ MPa and Poisson's ratio $\nu = 0.3$ is loaded in biaxial stress by normal stresses σ_x and σ_y (Figure 3).

A strain gage is bonded to the specimen at an angle 30°.

If the stress is $\sigma_x = 120$ MPa and the strain measured by the gage is $\varepsilon_{30o} = 407*10^{-6}$, compute:

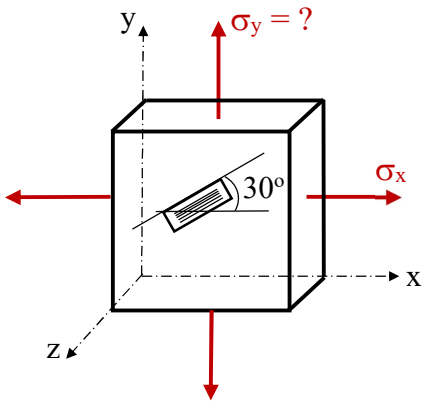

Figure 3

10 pts a) The normal stresses σ_y.

9 pts b) The maximum shear stress $(\tau_{max})_{xy}$ and shear strain $(\gamma_{max})_{xy}$ in the plane xy.

3 pts c) The maximum shear strain $(\gamma_{max})_{xz}$ in the plane xz.

3 pts d) The maximum shear strain $(\gamma_{max})_{yz}$ in the plane yz.

Question 4 (25 points)

The pipe with the material 1 (modulus of elasticity $E_1 = 2*10^5$ MPa, Poisson's ratio $\nu_1 = 0.3$ and coefficient of thermal expansion $\alpha_1 = 12*10^{-6}$ /°C), long and closed at the ends, is wrapped with a ring of material 2 ($E_2 = 70000$ MPa, Poisson's ratio $\nu_2 = 0.28$ and coefficient of thermal expansion $\alpha_2 = 20*10^{-6}$ /°C).

The inner radius of the pipe is $R_1 = 100$ mm. The pipe and ring thicknesses are $e_1 = 4$ mm and $e_2 = 5$ mm respectively (Figure 4).

Initially, there is a radial interference of 0.05 mm between the pipe and the ring.

Assuming the elastic domain, compute the contact pressure between the pipe and the ring when the assembly is heated by $\Delta T = 25$ °C and an internal pressure $p_1 = 20$ MPa is applied in the pipe.

Figure 4